KING COUNTY FLOOD CONTROL DISTRICT

Hazard Mitigation Plan

DRAFT

March 2010

HAZARD MITIGATION PLAN

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ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

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PART 1—THE PLANNING PROCESS

CHAPTER 1.
INTRODUCTION TO THE PLANNING PROCESS

1.1 DISASTER PLANNING OVERVIEW

Congress approved the federal Disaster Mitigation Act, commonly known as the DMA or the 2000 Stafford Act amendments, on October 10, 2000 (Public Law 106-390). This act required state and local governments to develop hazard mitigation plans as a condition for federal grant assistance. Prior to 2000, federal legislation provided funding for disaster relief, recovery, and some hazard mitigation planning. The DMA improves upon the planning process by emphasizing the importance of community planning for disasters before they occur. Implementing regulations are included in Title 44 of the Code of Federal Regulations, or 44CFR. The DMA defines local governments impacted by the law as follows:

> *Any county, municipality, city, town, township, public authority, school district, special district, intrastate district, council of governments (regardless of whether the council of governments is incorporated as a nonprofit corporation under state law), regional or interstate government entity, or agency or instrumentality of a local government, or Alaska Native Village or organization; and any rural community, unincorporated town or village, or other public entity.* (44CFR, Section 2.1.2)

As a newly formed special purpose district, the King County Flood Control District is obligated to prepare a hazard mitigation plan in order to comply with the DMA and become eligible for grant funding available to local governments under the Robert T. Stafford Act.

Hazard mitigation is any action taken to permanently eliminate or reduce long-term risks to human life and property from natural hazards. Along with preparedness, response, and recovery, mitigation is an essential element in emergency management. Disasters can have significant impacts on communities. They can destroy or damage life, property, and infrastructure, local economies, and the environment.

Using this initiative as a foundation for proactive planning, the district developed this hazard mitigation plan in an effort to reduce future loss of life and property resulting from disasters and to target risk reduction measures that will protect the critical functions of the facilities they maintain. It is impossible to predict exactly when and where these disasters will occur or the extent to which they will impact the district. However, with careful planning and collaboration among public agencies, stakeholders, and citizens, it is possible to minimize losses that can occur from disasters.

1.2 PURPOSES FOR PLANNING

The *King County Flood Control District Hazard Mitigation Plan* will assist the district in reducing its risk from all hazards by identifying resources, information, and strategies for risk reduction. The plan will also help guide and coordinate mitigation activities throughout the district. It was prepared to meet the following objectives:

- Meet DMA program requirements and thus gain eligibility to pursue grant funding from the Federal Emergency Management Agency, or FEMA.
- Be easy to incorporate as an all hazards appendix to the *2006 King County Flood Hazard Management Plan*.
- Generate risk assessment data that can be used to update the flood risk assessment of the 2006 flood hazard management plan.

1.3 WHO WILL BENEFIT FROM THIS PLAN?

The planning area for this plan is all of King County, and the ultimate beneficiaries of mitigation efforts are the residents and businesses of the county. The plan aims to reduce risks to district facilities from all hazards and risks to the general building stock and critical facilities countywide from flood related hazards. District operations protect those who live in, work in, and visit King County. Although this plan does not establish mandates for the district, it does provide a planning framework for all foreseeable hazards that may impact the district's service area. By establishing this plan, the district will be in a position to better leverage local levy funds with federal grants, ultimately providing more mitigation funding and flood hazard risk reduction projects—a direct benefit to the citizens of King County.

1.4 HOW TO USE THIS PLAN

This hazard mitigation plan is organized into three primary parts:

- Part 1—The Planning Process
- Part 2—The Risk Assessment
- Part 3—The Mitigation Strategy.

Each part includes elements required under 44CFR. The requirements specified for DMA compliance are often cited at the beginning of a subsection to illustrate compliance with the requirement. Maps provided with the risk assessment chapters (Chapters 9 – 15) are inserted at the end of each chapter.

CHAPTER 2.
ORGANIZING RESOURCES

The first phase in the development of the district's hazard mitigation plan was to organize resources for a successful planning effort. The district assessed its readiness for planning by establishing a planning committee, seeking technical assistance, securing support of the District Board of Supervisors, and engaging the public to determine its perception of risk and support of hazard mitigation. This phase also included coordination with local, state and federal agencies involved in hazard mitigation within the region to ensure a consistent platform with other ongoing efforts. This phase had the following primary objectives:

- Select a consultant to facilitate the process.
- Form a planning committee.
- Coordinate with other agencies.
- Review existing plans.
- Involve the public.

The first four objectives are discussed in this chapter; public involvement is discussed in Chapter 3.

2.1 CONSULTANT SELECTION

The district secured the services of Tetra Tech, Inc. to facilitate the plan development. The Tetra Tech team included a lead project planner, a risk assessment modeling lead, and a public policy support team member. The Tetra Tech team would lead all phases of the plan development, and would be the principal author of the plan.

2.2 PLANNING COMMITTEE FORMATION

A planning committee was formed of district and consultant staff. District personnel representing each river basin in King County were selected to serve on the committee, to provide a broad overview of district operations and capabilities. The makeup of the planning committee is as follows:

- Brian Murray—Countywide Policy and Programs Supervisor
- Priscilla Kaufmann—Project/Program Manager, Countywide Policy and Programs
- Saffa Bardaro—Communications Specialist, Countywide Policy and Programs
- Jason Wilkinson—Project/Program Manager, Countywide Policy and Programs
- Ken Zweig—Project/Program Manager, Countywide Policy and Programs
- Sally King—Project/Program Manager, South Fork Skykomish and Snoqualmie River Basins
- Katy Vanderpool—Project/Program Manager, Green and White River Basins
- Nancy Faegenburg—Project/Program Manager, Cedar and Sammamish River Basins
- Jeff Bowers—Assistant Director, Office of Emergency Management
- Rob Flaner—Tetra Tech, Inc., Lead Project Planner
- Ed Whitford—Tetra Tech, Inc., Risk Assessment Modeling Lead

- Laura Hendrix—Tetra Tech, Inc., Public Policy.

The planning committee met seven times between August 2009 and March 2010. At these meetings, the committee identified goals and objectives for the plan, provided overview and comment on risk assessment, reviewed existing programs that can support district risk reduction strategies, developed an action plan, established a prioritization strategy for the action plan, and developed a plan maintenance strategy. Meeting agendas, minutes and attendance logs are available for review.

2.3 OBTAINING SUPPORT FOR THE PROCESS

To be successful, mitigation planning requires collaboration among and support from all levels of county government. To ensure district support for this process, a briefing was provided to the King County Flood Control District Executive Committee on July 27, 2009. The District Executive Committee is a sub-committee of the District Board of Supervisors and oversees day-to-day management and organization of the district.

2.4 COORDINATION WITH OTHER AGENCIES

The DMA requires that opportunities for involvement in the planning process be provided to neighboring communities, local and regional agencies involved in hazard mitigation, agencies with authority to regulate development, businesses, academia, and other private and nonprofit interests (44CFR, Section 201.6(b)(2)). Agency involvement was accomplished as follows:

- **Agency Notification**—The following agencies were invited to participate in the planning process from the beginning and were kept apprised of plan development milestones:
  - FEMA Region X
  - Washington Emergency Management Division
  - Washington Department of Ecology
  - King County Office of Emergency Management
  - King County Department of Natural Resources and Parks, Water and Land Resources Division
  - King County Department of Development and Environmental Services
  - Flood Control District Basin Technical Committees
  - Flood Control District Advisory Committee
  - Flood Control District Executive Committee
  - Flood Control District Board of Supervisors
  - Unincorporated Area Councils
  - Water Resource Inventory Areas

  All of these agencies received notice of this process and participated to varying degrees throughout. This approach proved to be beneficial when these agencies supported the effort by attending meetings or providing feedback on issues. All of these agencies were also informed about the district's Web site for up-to-date information.

- **Pre-Adoption Review**—All the agencies listed above were provided the means to review and comment on the mitigation action plan. The predominant means for this review was through the district's Web site on the King County Web site. Each agency was sent an e-mail message informing them that draft portions of the plan were available for review. In addition, the complete draft plan was sent to FEMA Region X and the Washington Emergency Management Division for a pre-adoption review to ensure program compliance.

2.5 REVIEW OF EXISTING PLANS AND PROGRAMS

A hazard mitigation plan shall include a review and incorporation, if appropriate, of existing plans, studies, reports, and technical information as part of the planning process (44CFR, Section 201.6(b)(3)). There are two principal documents in effect in King County that will work in concert with this hazard mitigation plan to reduce risks to district facilities: the *2006 King County Flood Hazard Management Plan*, and the *King County Regional Hazard Mitigation Plan*.

2.5.1 2006 King County Flood Hazard Management Plan

On January 17, 2007, the King County Council adopted the *2006 King County Flood Hazard Management Plan*. This plan proposed much-needed improvements to King County's aging system of 500 levees and revetments that protect urban and rural floodplain residents, businesses, regional economic centers, public infrastructure and roads. It recommends contemporary flood hazard mitigation strategies to reduce flood risks to tens of thousands of people, billions of dollars in economic infrastructure and major transportation corridors.

The November 2006 flood event, which resulted in a federal disaster declaration, highlighted the urgent need to shore up King County's aging flood-protection system, as evidenced by saturated levees, sloughing, cracking and slumping. The district is fixing these failing flood protection facilities to reduce the likelihood of future flooding disasters.

2.5.2 King County Regional Hazard Mitigation Plan

In 2004, King County developed its first *Regional Hazard Mitigation Plan* in partnership with participating cities, school, utility and fire districts and emergency service providers. This plan was submitted to Washington State Emergency Management and reviewed and approved by FEMA. This effort was one of the steps in creating a community more resilient to natural, technological and societal hazard events and disasters. The King County Flood Control District had not been created at the time this plan was prepared, so the district is not included in the plan.

A five-year update of this multi-jurisdictional local plan was approved by FEMA on December 2, 2009, allowing King County to apply for FEMA hazard mitigation project grants and flood mitigation assistance project grants through December 2, 2014. The district did not participate in this update because it had decided to develop its own stand-alone hazard mitigation plan.

2.6 PLAN DEVELOPMENT CHRONOLOGY/MILESTONES

Table 2-1 summarizes important milestones in the plan's development, which consisted of five phases:

- Phase 1—Organize and review
- Phase 2—Develop the risk assessment
- Phase 3—Engage the public
- Phase 4—Assemble the plan
- Phase 5—Plan adoption/implementation.

**TABLE 2-1.
PLAN DEVELOPMENT CHRONOLOGY/MILESTONES**

Date	Event	Milestone	Attendance
7/27/2009	Management Support for the Process	• Briefing provided to the King County Flood Control District Executive Committee on the need for the plan and its proposed development process.	N/A
8/19/2009	1st Planning Committee Meeting	• Risk assessment data collection • Define critical facilities • Mission statement/goals/objectives • Outreach strategy	7
9/16/2009	2nd Planning Committee Meeting	• Risk assessment modeling update • Confirm goals • Identify objectives • Outreach strategy	7
10/21/2009	3rd Planning Committee Meeting	• Update on county regional plan • Risk assessment modeling update • Confirm objectives • Outreach strategy • Start thinking about actions	9
11/18/2009	4th Planning Committee Meeting	• Update on county regional plan • Risk assessment modeling update • Final objectives • Outreach update • Action plan	9
12/16/2009	5th Planning Committee meeting	• Update on county regional plan • Risk assessment modeling update • Outreach update • Action plan	8
1/20/2010	6th Planning Committee meeting	• Review revised timeline • Risk assessment-dam failure update • Outreach update • Review/revise action plans	9
1/22/2010	Web Site Deployment	• Web site dedicated to the hazard mitigation plan deployed on the district's Web site	N/A
2/17/2010	7th Planning Committee Meeting	• Develop/refine public meeting script • Risk assessment update • Review draft action plan	9
3/4/2010	Public Meeting	• Public open house to present risk assessment and draft action plan to the public for review and comment.	7
3/26/2010	Public Comment Period Begins	• Draft plan posted on district Web site for public comment	N/A
	Adoption Process		

CHAPTER 3.
PUBLIC INVOLVEMENT

Broad public participation in the planning process ensures that a hazard mitigation plan will consider different points of view about risks and potential actions to mitigate them. The DMA requires that the public have opportunities to comment on disaster mitigation plans during the drafting stages and prior to plan approval (44CFR, Section 201.6(b)(1)). The planning committee drafted a public involvement strategy using multiple media sources available to the district.

3.1 INVOLVEMENT OF EXISTING ORGANIZATIONS

The *King County Flood Control District Hazard Mitigation Plan* was prepared by a multidisciplinary team of King County employees. Opportunities were provided for input from the Flood Control District Basin Technical Committees, Advisory Committee, stakeholders, and the general public. County staff are responsible for implementing flood hazard management programs and projects, staffing the advisory and basin technical committees, providing technical and engineering assistance to cities, and reporting progress back to the Flood Control District Board of Supervisors, advisory committees, and basin technical committees. The public participation process for the *King County Flood Control District Hazard Mitigation Plan* used existing organizations as described in the following sections.

3.1.1 King County Flood Control District Organizations

Basin Technical Committees

The district formed basin technical committees to ensure that basin-scale issues and technical information are factored into the district's overall decision-making processes and to accomplish the following objectives:

- Provide input to district staff regarding capital improvement project priorities.
- Share relevant information across areas of the district that would influence implementation of the district's work program.
- Review and help guide project implementation, as appropriate.
- Develop policies and issue papers as required.
- Coordinate jointly with state and federal partners on relevant issues.

Basin technical committees are made up of staff from jurisdictions within each basin, as well as King County staff. Committee members were notified by e-mail on February 24, 2010 about the Web site set up for this hazard mitigation plan and the public meeting that was scheduled for March 4, 2010. Each committee reviewed and prioritized flood mitigation initiatives for their basin.

Flood Control District Advisory Committee

The advisory committee is composed of both permanent and two-year rotating members. The permanent seats on the committee are held by the King County Executive and the mayors, or council members designated by the mayor, of Tukwila, Auburn, Kent, Renton, Snoqualmie, North Bend, Carnation, Seattle and Bellevue. Four of the two-year rotating seats are held by mayors or city council members of other cities, nominated by the Suburban Cities Association. One of the two-year seats is held by an individual representing one of King County's Unincorporated Area Councils who is selected by the King County Council. The advisory committee was included in the planning process in the following ways:

- A presentation on the hazard mitigation plan was made to the committee November 19, 2009.
- E-mail notification was sent to committee members February 24, 2010, notifying them of the hazard mitigation plan Web site location and the public meeting scheduled for March 4, 2010
- An update presentation on the hazard mitigation plan was made to the committee on February 25, 2010, including reminder of the public scheduled meeting.

Flood Control District Executive Committee

The District Executive Committee functions as a sub-committee of the District Board of Supervisors and oversees daily management and organization of the district. A briefing on the development of the hazard mitigation plan was given to the committee on July 27, 2009.

Flood Control District Board of Supervisors

The District Board of Supervisors is responsible for approving the final hazard mitigation plan. The board consists of all members of the Metropolitan King County Council. It is responsible for developing a plan for funding maintenance and repairs of flood control facilities and for approving the *Flood Hazard Management Plan*. Members are as follows:

- Bob Ferguson, District 1
- Larry Gossett, District 2
- Kathy Lambert, District 3
- Larry Phillips, District 4
- Julia Patterson, District 5 (Board of Supervisors Chair)
- Jane Hague, District 6
- Peter von Reichbauer, District 7
- Jan Drago, District 8
- Reagan Dunn, District 9 (Executive Committee Chair)

3.1.2 Unincorporated Area Councils

The following Unincorporated Area Councils are independent entities recognized by the King County Council to provide communication between King County government and the residents of county unincorporated areas:

- Four Creeks Unincorporated Area Council
- Greater Maple Valley Area Council
- North Highline Unincorporated Area Council
- Upper Bear Creek Community Council
- Vashon-Maury Island Community Council
- West Hill Community Council.

The volunteer members of the six county-recognized councils are elected by local area residents. The March edition of the Unincorporated Area Councils' newsletter, sent to approximately 425 people, included an article about the hazard mitigation plan.

3.1.3 Water Resource Inventory Areas

Planning for Water Resource Inventory Areas, or WRIAs, was authorized under Washington's Water Resources Act of 1971 (formalized under Washington Administrative Code 173-500-040). There are four WRIAs within the King County Flood Control District: 7, 8, 9 and 10. A March 4, 2010 e-mail to WRIA stakeholders informed them of the development of the *King County Flood Control District Hazard Mitigation Plan*.

3.2 PUBLIC OUTREACH ACTIVITIES

3.2.1 Public Meetings

A public meeting was held in Issaquah, Washington, on Thursday, March 4, 2010 from 6 to 8 p.m. (see Figures 3-1). The meeting provided the public an opportunity to review and comment on draft goals and objectives for the hazard mitigation plan and maps that identify hazard areas and indicate risk levels to people and district property. The public meeting was advertised through a series of news releases, the Web site and newspaper articles.

Figure 3-1. Photos from March 4, 2010 Public Meeting In Issaquah

3.2.2 Press Releases

Press releases were prepared as key milestones were achieved over the course of the plan's development and prior to each public meeting. Press releases were distributed to local media on the following dates:

- February 10, 2010—"King County Flood Control District preparing hazard mitigation plan to ensure public safety"
- February 19, 2010—"King County Flood Control District preparing hazard mitigation plan to ensure public safety"

The *Issaquah Press* ran an article on February 24, 2010, "Learn about disaster risks and ways to prepare March 4."

3.2.3 Internet

Web pages for the *King County Flood Control District Hazard Mitigation Plan* were established on King County's Web site at the following address:

- www.kingcounty.gov/environment/waterandland/flooding/flood-control-zone-district/local-hazard-mitigation-plan-update.aspx

The Web site for the plan included the following elements:

- Overview of the hazard mitigation plan
- Advertisement of the public meeting
- A hazards map page that included maps and geographic information system, or GIS, data for flood hazard areas, dam failure, earthquake, liquefaction, landslide, lahar and wildfire.
- Draft goals and objectives of the hazard mitigation plan
- Draft hazard mitigation plan
- Planning committee meeting agendas and meeting minutes
- Consultant scope of work for the plan
- Frequently asked questions
- How to comment on the hazard mitigation plan.

Figure 3-2 shows a sample Web page for the project. The King County Flood Control District advertised the public meeting on its Web page. The City of Issaquah advertized the public meeting in its Web calendar of events (www.ci.issaquah.wa.us/).

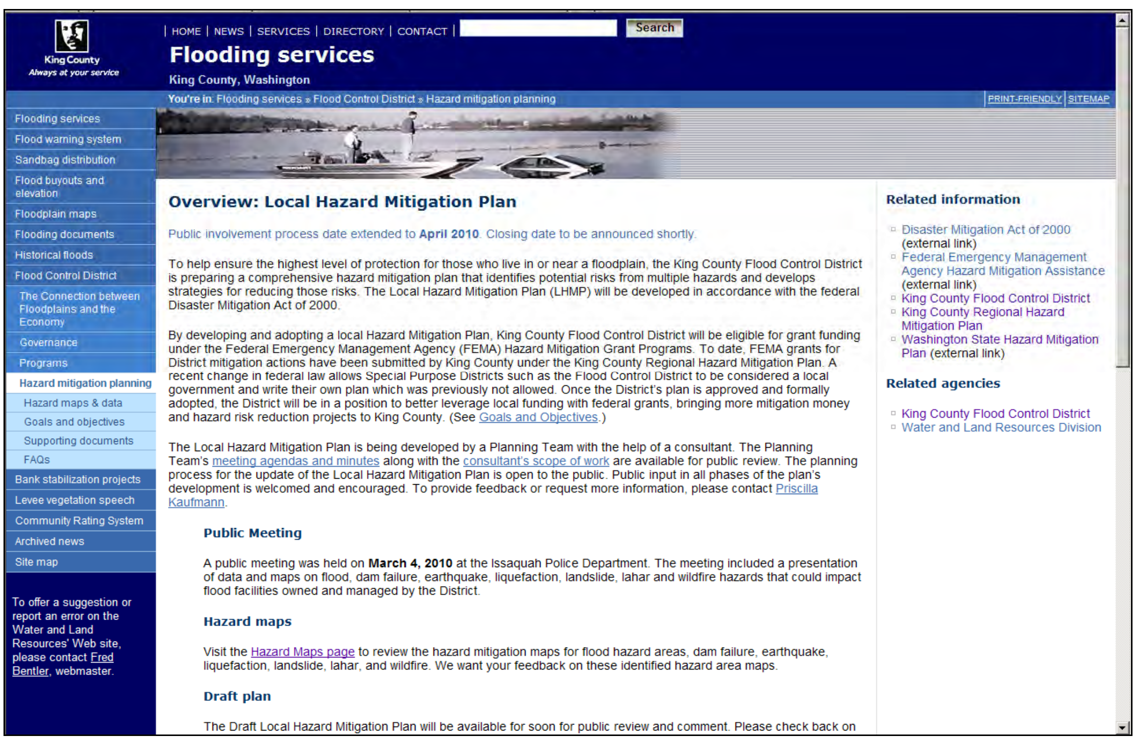


Figure 3-2. Sample Page from Hazard Mitigation Plan Web Site

CHAPTER 4.
GOALS AND OBJECTIVES

4.1 BACKGROUND

The DMA requires hazard mitigation plans to identify goals for reducing or avoiding long-term vulnerabilities to hazards (44CFR, Section 201.6(c)(3)(i)). The planning committee led a facilitated process to establish goals and objectives for this plan that are consistent with those of other local hazard planning documents. Goals and objectives were established using public input and data from a preliminary risk assessment. Common issues identified in this process were as follows:

- The capabilities of the district to implement mitigation actions for hazards other than flooding
- Potential damage to existing buildings from flooding and flood related hazards
- Environmental impacts of mitigation activities
- Interagency coordination
- Reduction of repetitive losses
- Economic impact of hazard events.

The planning committee selected goals and objectives to address these issues and guide the mitigation strategies of this plan.

4.2 GOALS AND OBJECTIVES

Goals and objectives are defined as follows for this plan:

- **Goals** are general guidelines that explain what benefits are to be achieved. They are broad, long-term, statements and represent global visions. The success of a plan should be measured by the degree to which its goals have been met (that is, by the actual benefits achieved in terms of hazard mitigation).
- **Objectives** are short-term aims which, when combined, form a strategy or course of action to meet a goal. Unlike goals, objectives are specific and measurable.

4.2.1 Goals

The planning committee identified the following goals for the hazard mitigation plan:

1. Protect life and property.
2. Support emergency services.
3. Promote public awareness.
4. Encourage the development and implementation of long-term, cost-effective and environmentally sound flood risk reduction projects.
5. Leverage partnering opportunities.

A consistency review determined that these goals are consistent with those of the *King County Regional Hazard Mitigation Plan*, the *2006 King County Flood Hazard Management Plan*, and the *Washington State Enhanced Hazard Mitigation Plan*.

4.2.2 Objectives

The planning committee selected objectives that would meet multiple goals, as listed in Table 4-1. The objectives serve as a stand-alone measurement of a mitigation action, rather than as a subset of a goal. Achievement of the objectives will be a measure of the effectiveness of a mitigation strategy. The objectives also are used to help establish priorities.

TABLE 4-1.
HAZARD MITIGATION PLAN OBJECTIVES

Objective Number	Objective Statement	Goals to Which It Can Be Applied
O-1	Protect and maintain critical facilities, including levees and revetments, within the district.	1, 2, 4
O-2	Improve floodplain conveyance through modification or removal of flood facilities when appropriate.	1, 2, 4
O-3	Utilize best available data to identify the location and potential impacts of natural hazards on people, property and the natural environment.	1, 2, 3, 5
O-4	Improve systems that provide warning and emergency communications.	1, 2, 3, 5
O-5	Retrofit, purchase, or relocate structures in high hazard areas including those known to be repetitively damaged within the capabilities of the district.	1, 2, 4, 5
O-6	Coordinate district hazard mitigation efforts, including planning and projects, with other mitigation efforts within the planning area to leverage all potential partnerships.	1, 2, 3, 4, 5
O-7	Inform the public about the risk exposure to natural hazards and ways to increase the public’s capability to prepare, respond, recover and mitigate the impacts of these events.	1, 2, 3, 5
O-8	Increase the resilience and the continuity of operations of identified critical facilities within the district.	1, 2, 5
O-9	Support programs within the planning area that are recognized under the federal Community Rating System.	1, 2, 3
O-10	Seek mitigation projects that provide the highest degree of natural hazard protection at the least cost.	1, 4, 5
O-11	Seek risk reduction projects that minimize or mitigate their impacts on the environment.	1, 4, 5
O-12	Where feasible, support agricultural preservation within the context of sound floodplain management.	1, 3, 5

CHAPTER 5.
PLAN ADOPTION

5.1 PRE-ADOPTION REVIEW

A hazard mitigation plan must be formally adopted by the governing body of the jurisdiction requesting federal approval of the plan (44CFR, Section 201.6(c)(5)). A draft version of this plan will be submitted to the Washington Emergency Management Division prior to adoption for a pre-adoption review. Once the plan has been determined to comply with the criteria specified under the DMA, the Washington Emergency Management Division will forward it to FEMA Region X for review and approval. Simultaneously with these reviews, the draft action plan will be sent to the following agencies with a request for review and comment:

- King County Emergency Management
- Flood Control District Basin Technical Committees
- Flood Control District Advisory Committee
- King County Unincorporated Area Councils
- WRIAs 7, 8 and 9
- Flood Control District Board of Supervisors
- Washington Department of Ecology.

5.2 DISTRICT ADOPTION PROCESS

Once pre-adoption approval has been granted by the Washington Emergency Management Division and FEMA Region X, the district will initiate its process to formally adopt the plan. The plan will be submitted to the District Executive Committee for review and input before it is forwarded to the District Board of Supervisors for adoption.

5.3 ADOPTION

Pre-adoption approval of the plan was granted by the Washington Emergency Management Division on __________, and by FEMA Region X on ________.

The King County Flood Control District Board of Supervisors adopted the plan through Resolution #____________ on _______, 2010. A copy of the resolution is provided in Figure 5-1.

Final FEMA approval was granted on __________, 2010. The King County Flood Control District is considered eligible for the benefits afforded under the DMA as of this date.

Figure 5-1. Resolution Adopting the King County Flood Control District Hazard Mitigation Plan

CHAPTER 6.
PLAN MAINTENANCE STRATEGY

6.1 OVERVIEW

A hazard mitigation plan must present a plan maintenance strategy that includes the following (44CFR, Section 201.6(c)(4)):

- A method and schedule for monitoring, evaluating, and updating the mitigation plan
- A process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate
- A strategy for continuing public participation through the plan maintenance process.

The district will adopt the following plan maintenance protocol identified in the *2006 King County Flood Hazard Management Plan*:

> *The 2006 King County Flood Hazard Management Plan will be updated every five years, in accordance with Community Rating System requirements. Additionally, progress of the Plan will be monitored annually in the form of a progress report as required by the Community Rating System annual recertification process. Specific information to be addressed in future updates includes an updated identification and delineation of flood hazard areas based on any flooding that had occurred since the last revision; new mapping; annexations and incorporations; changes in repetitive loss properties; increases in development within the floodplain or watershed; changes in flood protection facilities; and project and program flood risk reduction recommendations. Future Plan updates will be developed with input from agency, citizen and other stakeholders. New information and refined knowledge will inform the adaptive management implementation framework, update processes, and maintain the relevance of this Plan.*

The proposed plan maintenance strategy will ensure that the *King County Flood Control District Hazard Mitigation Plan* remains an active and relevant document. It includes a schedule for monitoring and evaluating the plan annually and producing an updated plan every five years. It also describes how the district will integrate public participation throughout the plan maintenance and implementation process. Finally, it explains how the district intends to incorporate the mitigation strategies outlined in this plan into existing planning mechanisms and programs.

6.2 PLAN IMPLEMENTATION

This plan includes a range of action items to reduce loss from hazard events in the King County Flood Control District. The effectiveness of the plan depends on its implementation and incorporation into the existing *2006 King County Flood Hazard Management Plan*. Together, these two plans can provide a framework for activities that the district can implement over the next five years. The planning committee has identified actions that will be implemented through existing plans, policies, and programs, resources permitting. The prioritization of capital projects reflects the district’s prioritized 6-year capital program, and is determined based on the consequence, severity, and urgency of the flood risk. Oversight of the implementation of the plan will be provided by district staff overseeing implementation of the capital projects identified in the flood hazard management plan.

6.3 ANNUAL PROGRESS REPORT

Until fully incorporated into the flood hazard management plan, this hazard mitigation plan will be monitored annually via reports to the District Board of Supervisors, as required under an inter-local agreement between the district and King County. This review by district staff will include the following:

- Summary of any hazard events that occurred during the performance period and the impact these events had on the planning area
- Review of mitigation success stories
- Review of continuing public involvement
- Brief discussion about progress implementing risk reduction strategies
- Re-evaluation of the action plan to determine if the timeline for identified projects needs to be amended (such as changing a long-term project to a short-term project because of funding availability)
- Recommendations for new projects
- Changes in or potential for new funding options (grant opportunities)
- Impact of any other local planning programs or initiatives that involve hazard mitigation.

6.4 PLAN UPDATE

Local hazard mitigation plans must be reviewed, revised if appropriate, and resubmitted for approval to remain eligible for benefits under the DMA (44CFR, Section 201.6(d)(3)). The district intends to update this plan on a 5-year cycle from the date of initial plan adoption. This cycle may be accelerated to less than 5 years based on the following triggers:

- A Presidential Disaster Declaration that impacts King County
- A hazard event that causes loss of life.

The plan's format allows the district to review and update sections when new data become available. New data can be easily incorporated, resulting in a plan that will remain current and relevant. Future updates will, at a minimum, include the following elements:

- The update process will be convened through a planning committee.
- Annual progress reports will identify potential changes.
- The risk assessment will be reviewed and updated using the best available information and technologies.
- The action plan will be reviewed and revised to account for any initiatives completed, dropped, or changed and to account for changes in the risk assessment or new district policies identified under other planning mechanisms, as appropriate.
- The draft update will be sent to appropriate agencies and organizations for comment.
- The public will be given an opportunity to comment on the update prior to adoption.
- The District Board of Supervisors will adopt the updated plan.

6.5 CONTINUING PUBLIC INVOLVEMENT

The public will continue to be apprised of the plan's progress through the district's Web site and through distribution of the annual progress reports for the district. Copies of the plan will be distributed to the

King County Library. Upon initiation of future update processes, a new public involvement strategy will be initiated based on guidance from the steering committee. This strategy will be based on the needs and capabilities of the district at the time of the update. At a minimum, this strategy will include the use of local media outlets within the planning area.

6.6 INCORPORATION INTO OTHER PLANNING MECHANISMS

It is the district's desire to fully incorporate this multi-hazard mitigation plan as an appendix to the *King County Flood Hazard Management Plan* during the next update to the flood plan. The flood hazard management plan is scheduled to be updated during 2010 and 2011, with formal adoption in early 2012. This update process will provide an opportunity to incorporate the hazard mitigation plan and create a single planning document for the district that will meet multiple program requirements.

The district has chosen to meet the requirements of the DMA as a single jurisdiction, and not participate as a planning partner in the *King County Regional Hazard Mitigation Plan*, for the following reasons:

- A stand-alone plan qualifies the district to apply for federal grant funding separately from King County to maximize grant opportunities.
- A stand-alone plan can be linked to the *King County Flood Hazard Management Plan*, which will be updated by January 2012, tying together the maintenance cycle of the two documents.

While the district will not be annexed to the regional plan, it is fully committed to supporting the regional plan as a stakeholder by sharing relevant data and coordinating hazard mitigation actions.

PART 2—RISK ASSESSMENT

CHAPTER 7.
RISK ASSESSMENT METHODOLOGY AND GENERAL CONCEPTS

7.1 INTRODUCTION

The risk assessment for this hazard mitigation plan evaluates the risk of natural hazards prevalent within the district's service area and meets requirements of the DMA (44CFR, Section 201.6(c)(2)). Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. This process focuses on the following elements:

- Hazard identification—The systematic use of all available information to determine what types of disasters may affect a jurisdiction, how often these events can occur, and the potential severity of their consequences.
- Vulnerability identification—The process of determining the impact of these events on the people, property, environment, economy and lands of a region
- Estimation of the cost of damage or cost that can be avoided through mitigation.

In addition to benefiting mitigation planning, risk assessment information allows emergency management personnel to establish early response priorities by identifying potential hazards and vulnerable assets.

7.2 METHODOLOGY

Chapters 9 through 15 describe the risks associated with each of seven hazards of concern identified as having a possible impact on district facilities. Each chapter elaborates on the hazard and the district's vulnerabilities and probable event scenarios. The following steps were used to define the risk of each hazard:

- Identify and profile each hazard—This assessment includes the following information for each hazard:
  - Geographic areas most affected by the hazard
  - Event frequency estimates
  - Severity estimates
  - Warning time likely to be available for response.
- Determine exposure to each hazard—Exposure was determined by overlaying hazards with an inventory of potentially vulnerable structures (flood hazard only), facilities, and systems to determine which of them would be exposed to each hazard. The King County geographical information system, or GIS, database contains extensive coverage of infrastructure.
- Assess the vulnerability of exposed facilities—Vulnerability of the exposed structures and infrastructure was determined by interpreting the probability of occurrence of each event and assessing structures, facilities, and systems that are exposed to each hazard. Tools such GIS and FEMA's hazard-modeling program called HAZUS were used to perform this assessment for the flood, dam failure and earthquake hazards. Outputs similar to those from HAZUS were generated for other hazards, using maps generated by the HAZUS program.

It should be noted that, except for the flood hazard and dam failure assessments, all of the assessments of exposure and vulnerability focus on King County Flood Control District facilities and not general building stock within the geographic limits of the district. Mitigation of hazards other than flooding on general building stock and non-district critical facilities falls outside the scope of the district's mission.

7.3 IDENTIFIED HAZARDS OF CONCERN

The planning committee considered the full range of natural hazards that could impact the area, and then identified and ranked the hazards that present the greatest concern. The identification process incorporated review of the *Washington State Enhanced Hazard Mitigation Plan* and the *King County Regional Hazard Mitigation Plan*; local, state and federal information on the frequency, magnitude and costs associated with hazards that have impacted or could impact the planning area; and qualitative or anecdotal information regarding natural hazards and the perceived vulnerability of the district's assets to them. Based on this review, seven natural hazards were identified as hazards of concern for this plan:

- Flooding
- Dam failure
- Earthquake
- Landslide
- Severe weather
- Volcano (lahar)
- Wildland fire.

Two other natural hazards—drought and tsunami—could occur in King County, but have a low potential to occur or to result in significant impacts on district facilities. These hazards are not addressed in this version of the plan but could be included in future updates, if deemed necessary by the district.

Technological hazards, such as hazardous material incidents, and man-made hazards, such as terrorist acts, are not addressed in this plan. The DMA regulations do not require consideration of such hazards, and due to limited funding, the district chose not to include them in this plan.

7.4 RISK ASSESSMENT TOOLS

7.4.1 Dam Failure, Earthquake and Flood—HAZUS-MH

Overview

In 1997, FEMA developed the standardized Hazards U.S., or HAZUS, model to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. HAZUS was later expanded into a multi-hazard methodology, HAZUS-MH, with new models for estimating potential losses from wind (hurricanes) and flood (riverine and coastal) hazards.

HAZUS-MH is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical facility, transportation and utility lifeline, and multiple models to estimate potential losses from natural disasters. The program maps and displays hazard data and the results of damage and economic loss estimates for buildings and infrastructure. Its advantages include the following:

- Provides a consistent platform and methodology for assessing risk across geographic and political entities.
- Provides a framework in which to save data so that it can readily be updated as population, inventory, and other factors change and as mitigation planning efforts evolve.
- Facilitates the review of mitigation plans because it helps to ensure that FEMA methodologies are incorporated.
- Supports FEMA grant application processes in calculating benefits using FEMA's definitions and terminology.
- Produces outputs that can be used to support communication and interaction with local stakeholders, a requirement of the mitigation planning process.
- The model is administered by the local government and can be used to manage and update a hazard mitigation plan throughout its implementation.

The version used for this plan was HAZUS-MH MR3, released by FEMA in September 2007. New data and tools released with MR3 include the following:

- Building valuations are updated.
- Building counts for single-family dwellings and manufactured housing are based on census counts instead of calculations.
- New tools in the flood model enable the user to import user-supplied flood maps and flood depth grids or generate a flood depth grid using specified Digital Flood Insurance Rate Map floodplain boundaries and digital elevation grids.

Levels of Detail for Evaluation

HAZUS-MH provides default data for inventory, vulnerability and hazards; this default data can be supplemented with local data to provide a more refined analysis. The model can carry out three levels of analysis, depending on the format and level of detail of information about the planning area:

- **Level 1**—All of the information needed to produce an estimate of losses is included in the software's default data. This data is derived from national databases and describes in general terms the characteristic parameters of the planning area.
- **Level 2**—More accurate estimates of losses require more detailed information about the planning area. To produce Level 2 estimates of losses, detailed information is required about local geology, hydrology, hydraulics and building inventory, as well as data about utilities and critical facilities. This information is needed in a GIS format.
- **Level 3—**This level of analysis generates the most accurate estimate of losses. It requires detailed engineering and geotechnical input to customize the methodology specific to the planning area.

Application for This Plan

The following methods were used to assess specific hazards for this plan:

- **Flood**—A modified Level 2 analysis was performed. The valuation of general building stock and the estimates of losses in King County were based on an updated general building stock database. King County Assessor data was used to update cost, square footage, and building count. An updated inventory provided by the county was used in place of the HAZUS-MH defaults for essential facilities and user-defined facilities. Current Digital Flood Insurance

Rate Maps for King County were used to delineate the flood hazard areas and estimate potential losses from the 100- and 500-year flood events. Using the Digital Flood Insurance Rate Map floodplain boundaries and LiDAR digital elevation grids, a flood depth grid was generated. The flood depth grid was integrated into the model and the river hydraulic analysis was run for mean return periods.

- **Dam Failure—**Dam failure inundation mapping for King County was collected where available. This data was imported into HAZUS-MH and a modified Level 2 analysis was run using the flood methodology described above, focusing on the 500-year floodplain within the dam failure inundation areas. General building stock and essential facilities were modeled.
- **Earthquake**—A Level 2 HAZUS-MH analysis was performed to analyze the earthquake hazard losses for district facilities. An updated inventory of facilities was used in place of the HAZUS-MH defaults. Earthquake shake maps and probabilistic data prepared by the U.S. Geological Survey, or USGS were used for the analysis of this hazard.

7.4.2 Landslide, Severe Weather, Volcano and Wildland Fire

For most of the hazards evaluated in this risk assessment, historical data was not adequate to model future losses. However, HAZUS-MH is able to map hazard areas and calculate exposures if geographic information is available on the locations of the hazards and inventory data. Areas and inventory susceptible to some of the hazards of concern were mapped and exposure was evaluated. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment. District relevant information was gathered from a variety of sources. Frequency and severity indicators include past events and the expert opinions of geologists, emergency management specialists and others. To the extent possible, hazard locations were mapped using GIS. The primary data source was the King County GIS database, augmented with state and federal data sets. Additional data sources for specific hazards were as follows:

- **Landslide**—Landslide data included the following:
  - King County Sensitive Areas Ordinance Landslide data, defined as a combination of slope greater than 15%, impermeable soils, and springs or groundwater seepage.
  - Washington Department of Natural Resources Geology and Earth Resources Division landslide data, which includes a compilation of previously mapped landslides by a variety of sources at multiple map scales.
- **Severe Weather**—Severe weather data was downloaded from the Natural Resources Conservation Services and the National Climatic Data Center.
- **Volcano—**Volcanic hazard data was obtained from the U.S. Geological Survey Cascade Volcano Observatory.
- **Wildland Fire**—The Washington State Department of Natural Resources provided data for communities at risk at wildland-urban interface areas, or WUIAs.

7.4.3 Limitations

Loss estimates, exposure assessments and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

- Approximations and simplifications necessary to conduct a study
- Incomplete or outdated inventory, demographic, or economic parameter data

- The unique nature, geographic extent and severity of each hazard
- Mitigation measures already employed
- The amount of advance notice residents have to prepare for a specific hazard event.

These factors can result affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate. These results do not predict precise results and should be used only to understand relative risk. Over the long term, King County and the district will collect additional data to assist in estimating potential losses associated with other hazards.

7.5 CLIMATE CHANGE

According to the National Academy of Sciences, the earth's surface temperature has risen by about 1 degree Fahrenheit in the past century, with accelerated warming during the past two decades. Most warming over the last 50 years is attributed to human-caused global warming. Around the world and in the Pacific Northwest, noticeable changes in natural resources and plants and animals have been associated with this warming, from shrinking glaciers and mountain snowpacks to altered migratory patterns. These changes are expected to continue as global warming intensifies. Climate change could have several impacts on the occurrence and severity of natural hazards around the world:

- Higher temperatures
- Changing landscapes
- Wildlife at risk
- Sea level rise
- Increased risk of drought, fire and floods
- Stronger storms and increased storm damage
- More heat-related illness and disease
- Economic losses.

In the coming decades, climate change is expected to exacerbate the risks of disasters, not only from more frequent and intense hazard events but also through greater vulnerability to existing hazards. More frequent and intense storms and floods and long-lasting droughts can erode existing community capacity to prepare, respond and rebuild after successive hazard events. Adverse impacts of climate change on public health, ecosystems, food security, migration and vulnerable groups such as children, the elderly and women will increase the vulnerability of communities to natural hazards of all types.

This hazard mitigation addresses climate change as a subset or secondary impact for each identified hazards of concern. Therefore, each chapter of this plan addressing one of the hazards of concern includes a section on the probable impacts of climate change for that hazard.

7.6 PRESIDENTIAL DISASTER DECLARATIONS

Presidential disaster declarations are typically issued for events that cause more damage than state and local governments can handle without assistance from the federal government, although no specific dollar loss threshold has been established for these declarations. A presidential disaster declaration puts federal recovery programs into motion to help disaster victims, businesses and public entities. Some of the programs are matched by state programs. King County has been experienced 24 events since 1960 for which presidential disaster declarations were issued. Many if not all of these events impacted district facilities in some way. These events are listed in Table 7-1.

**TABLE 7-1.
PRESIDENTIAL DISASTER DECLARATIONS FOR HAZARD EVENTS IN KING COUNTY**

Type of Event	Disaster Declaration #	Date
Severe Winter Storm and Record and Near Record Snow	1825	3/2/2009
Severe Winter Storm, Landslides, Mudslides, and Flooding	1817	1/30/2009
Severe Storms, Flooding, Landslides, and Mudslides	1734	12/8/2007
Severe Winter Storm, Landslides, and Mudslides	1682	2/14/2007
Severe Storms, Flooding, Landslides, and Mudslides	1671	12/12/2006
Severe Storms and Flooding	1499	11/7/2003
Nisqually Earthquake	1361	3/1/2001
Severe Storms, Flooding, Landslides, and Mudslides	1172	4/2/1997
Severe Winter Storms, Flooding	1159	1/17/1997
Severe Storms, Flooding	1100	2/9/1996
Storms, High Winds, Floods	1079	1/3/1996
Severe Storm, High Winds	981	3/4/1993
High Tides, Severe Storm	896	3/8/1991
Flooding, Severe Storm	883	11/26/1990
Flooding, Severe Storm	852	1/18/1990
Severe Storms, Flooding	784	12/15/1986
Severe Storms, Flooding	757	2/15/1986
Mt. St. Helens Volcanic Eruption	623	5/1980
Storms, High Tides, Mudslides, Flooding	612	12/31/1979
Severe Storms, Mudslides, Flooding	545	12/10/1977
Severe Storms, Flooding	492	12/13/1975
Heavy Rains, Flooding	328	3/24/1972
Earthquake	196	5/1965
Heavy Rains and Flooding	185	12/29/1964

7.7 CRITICAL FACILITIES AND INFRASTRUCTURE

Critical facilities and infrastructure are those that are essential to the health and welfare of the population. These become especially important after a hazard event. Critical facilities are typically defined to include police and fire stations, schools and emergency operations centers. Critical infrastructure can include roads and bridges that provide ingress and egress and allow emergency vehicles access to those in need and utilities that provide water, electricity and communication services to the community. Also included are Tier II facilities and railroads, which hold or carry significant amounts of hazardous materials with a potential to impact public health and welfare during a hazard event. The definition of critical facilities from the King County Critical Areas ordinance was used for this plan (King County Code 21A.06.260):

> *Critical facility is a facility necessary to protect the public health, safety and welfare including, but not limited to, a facility defined under the occupancy categories of "essential*

> *facilities," "hazardous facilities" and "special occupancy structures" in the structural forces chapter or succeeding chapter in K.C.C. Title 16. Critical facilities also include nursing and personal care facilities, schools, senior citizen assisted housing, public roadway bridges and sites that produce, use or store hazardous substances or hazardous waste, not including the temporary storage of consumer products containing hazardous substances or hazardous waste intended for household use or for retail sale on the site.*

Due to the scope of the district's mission, a comprehensive risk assessment of general building stock and countywide critical facilities was performed only for the flood and dam failure hazards. Risk assessments for the other hazards focused on district facilities. For dam failure and flood, a database of critical facilities in King County was created to identify vulnerabilities. The risk assessments for these hazards address critical facilities qualitatively. Due to the sensitivity of this information, a detailed list of facilities is not provided in this plan. The list is on file with King County Emergency Management.

CHAPTER 8.
KING COUNTY FLOOD CONTROL DISTRICT PROFILE

8.1 INTRODUCTION

King County has experienced 15 floods for which presidential disaster declarations were issued since 1960. These flood events affect nearly every resident of King County as well as other citizens who commute through or conduct business in the county. Flooding poses serious threats to public health, safety and welfare and can negatively impact transportation corridors and economic activities throughout the county. King County has become nationally recognized for its flood mitigation efforts and multi-objective approach to floodplain management. The county currently ranks as the top-rated county in FEMA's Community Rating System floodplain management program, or CRS.

Washington state law gives counties the authority to establish basinwide or countywide flood control districts to generate funding for operation and maintenance of flood control projects. In April 2007, the King County Council created the King County Flood Control District to provide funding and policy oversight for flood protection projects and programs in the county. The district's primary responsibility is to reduce flood and channel migration risk by rehabilitating levees and revetments, acquiring repetitive loss properties and other high-risk floodplain properties, increasing public awareness of flood hazards, improving countywide flood warning, and expanding flood prediction capabilities.

The district is tasked with acquiring and allocating funding to improve approximately 500 aging flood protection facilities. These facilities span nearly 120 miles within King County. They protect major business centers, residential property and critical public infrastructure. Existing facilities protect at least $7 billion of assessed value, including Boeing aerospace plants, the Southcenter Mall and primary distribution centers for medical facilities, grocery stores and gas stations. Approximately 65,000 jobs are located within these flood-protected areas. It is estimated that a one-day shutdown of economic activity in these floodplains would cost the region at least $46 million in lost economic output.

8.2 GOVERNANCE

The King County Flood Control District is an independent special purpose district of the State of Washington. Figure 8-1 illustrates the district's overall governance structure. Revised Code of Washington RCW 86.15 authorizes the King County Council to be the governing body for the district, and the King County Council was established as such under King County Council Ordinance 15728. Nine council members oversee the district's funding, projects, policies and programs as the District Board of Supervisors. The board serves as the primary governing body and decision-maker. The District Advisory Committee provides the District Board of Supervisors with expert policy advice on regional flood protection and annual budgeting issues and recommends priorities and implementation strategies for the district's capital improvement program.

Staff from the King County Department of Natural Resources and Parks Water and Land Resources Division, River and Floodplain Management Section are responsible for developing and implementing board-approved flood protection projects and programs.

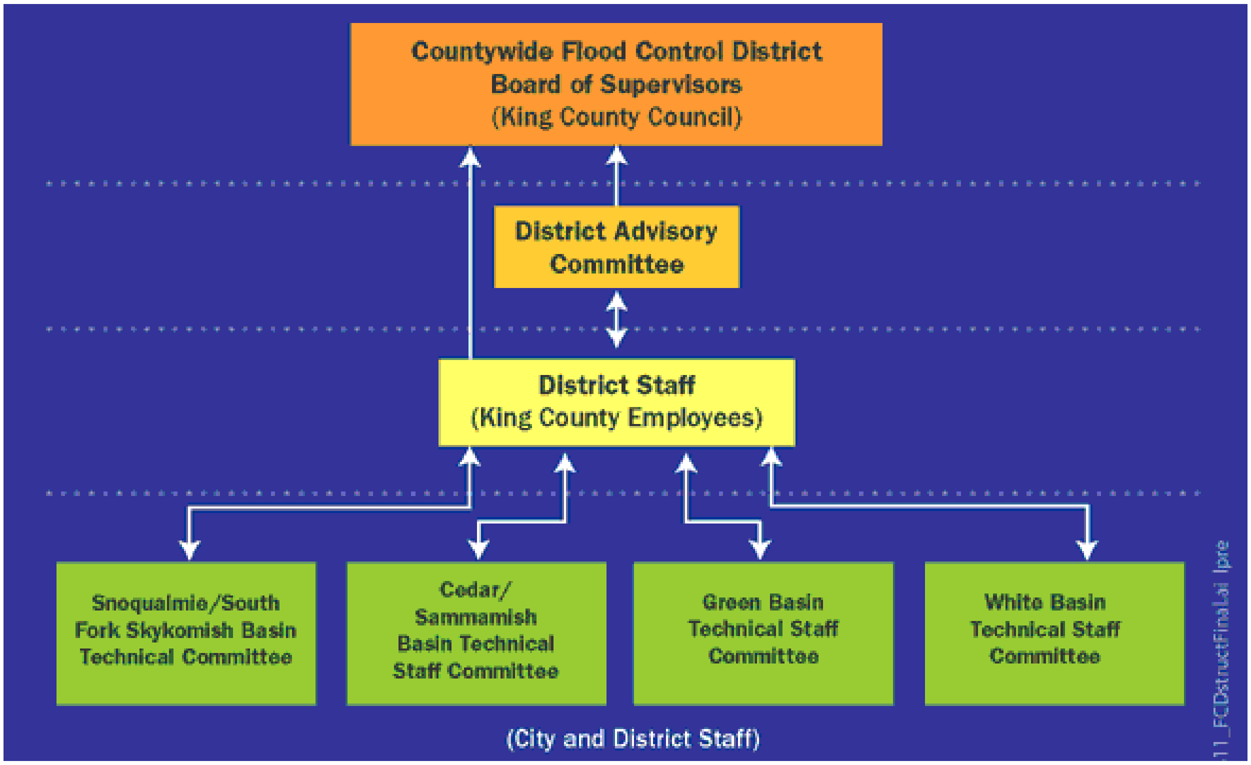


Figure 8-1. King County Flood Control District Governance Structure

Basin technical committees serve the district's major river basins: Snoqualmie/South Fork Skykomish Rivers, Cedar/Sammamish Rivers, Green/Duwamish River and White River (see Figure 8-2). These committees ensure that basin-scale issues and basin-specific technical information are considered in regional decision-making. Committee members are staff from local governments in each basin along with district staff. Tribal governments also are invited to participate. Together, basin committee members coordinate with state and federal partners, review and guide flood hazard management projects and share information on relevant flood issues.

8.3 FUNDING

The King County Flood Control District was created to ensure that sufficient funding would be available to address the maintenance, repair and reconstruction of King County's aging critical flood protection facilities. Most of the 500 or so flood protection facilities in King County were built in the early 1960s. The structures are not built to today's engineering standards and many are now reaching the end of their lifespan. King County's flood protection infrastructure must be strengthened to protect not only lives and homes, but also area businesses that are crucial to the region's economy. A flood could pose a significant risk to public safety, regionally important economic centers and transportation corridors. It is estimated that up to $345 million in priority repairs and upgrades are needed on the multiple flood containment levees and bank stabilization projects throughout the county. Prior to the development of the district, funding was not sufficient to maintain or rebuild these facilities.

The district is funded by a countywide property levy tax established at 10 cents per $1,000 of assessed value. This equals about $40 per year on a $400,000 home. This levy is applied to residential, commercial and industrial properties in both unincorporated and incorporated jurisdictions within King County.

Figure 8-2. King County Flood Control District Basins

The levy generates roughly $35 million each year and increased the number of flood-control projects funded by King County from only two or three a year to about 55 projects in 2008. About 85 percent of the funds are used to address a backlog of infrastructure repair needs, with the remainder supporting other floodplain management activities such as flood facility maintenance, flood awareness programs, flood warning systems and continued participation in FEMA's CRS program. The funding has also increased the district's ability to leverage state and federal matching funds (approximately $28 million in 2008).

By developing and adopting a local hazard mitigation plan, the district will be eligible for post-disaster mitigation grants from the FEMA Hazard Mitigation Grant Program. Previously, FEMA grant applications for district mitigation activities had been submitted by King County under the *King County Regional Hazard Mitigation Plan*. A recent change in federal law allows special purpose districts to develop their own plan. Upon approval and adoption of the hazard mitigation plan, the district will be better able to leverage local levy funds with federal grants, ultimately providing more mitigation funding and flood hazard risk reduction projects to King County.

8.4 PROGRAMS AND PROJECTS

The *2006 King County Flood Hazard Management Plan* identifies and recommends a suite of projects, programs and policies to address flooding issues in King County. Stated goals of the plan are to reduce risks from flood and channel migration hazards; to avoid or minimize the environmental impacts of flood hazard management; and to reduce the long-term costs of flood hazard management. The flood hazard management plan identifies $345 million in priority repairs and upgrades. It also provides for flood preparedness, a regional flood warning center and emergency response system, post-flood recovery, flood facility maintenance and monitoring, public education and outreach, flood hazard planning, mitigation and grants, flood mapping and technical studies, and mechanisms for citizen inquiry and public input.

The King County Flood Control District is responsible for executing and updating the flood hazard management plan. The district's key strategies and objectives include:

- Reducing risk by permanently removing flood, erosion, and landslide prone residential structures
- Minimizing creation of new risks to public safety from development pressure.
- Reducing risk exposure by elevating structures and strengthening flood facilities
- Improving floodwater conveyance and capacity by reconnecting rivers to their floodplain
- Providing safe access to homes and businesses by protecting key transportation routes

King County's River and Floodplain Management Section carries out the district's approved flood protection programs and projects. The district also coordinates with local, tribal, state and federal agencies, as well as area watershed groups. A series of successful capital improvement projects have been undertaken by the district, including levee and revetment repair and replacement projects, home elevation efforts and acquisition of repetitive loss properties (including the relocation of entire mobile home parks). Still, projects in high risk areas throughout King County remain in need of mitigation funding.

CHAPTER 9.
FLOOD

9.1 FLOOD DEFINED

> **Note:** King County prepared a comprehensive flood hazard management plan in 2006 that is the principal policy document for the King County Flood Control District. This chapter summarizes much of the data contained in that document. More detail on flooding issues and concepts is available in the *2006 King County Flood Hazard Management Plan* at:
>
> www.kingcounty.gov/environment/waterandland/flooding/documents/flood-hazard-management-plan.aspx

The following definitions apply in the discussion of flood hazards:

- **Flood**—A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters or the unusual and rapid accumulation of runoff of surface waters from any source.
- **Floodplain**—The total area subject to inundation by water from any natural source. The 100-year floodplain is the area subject to inundation during the "base flood," or the flood that has a 1 percent chance of being equaled or exceeded in any given year.

9.2 GENERAL BACKGROUND

A floodplain is usually low land adjacent to a river, creek or lake. The extent of floodplain inundation depends partly on flood magnitude, defined by the return frequency of a particular flood. Because they border water bodies, floodplains have historically been popular sites to establish settlements, which become susceptible to flood-related disasters.

Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon. Floodplains generally contain unconsolidated sediments, often extending below the bed of the stream or river. Geologically ancient floodplains are often represented in the landscape by terrace deposits, which remain relatively high above current deposits, and can indicate former courses of rivers and streams.

Floodplains can support ecosystems that are rich in biological quantity and diversity. Wetting of the floodplain soil releases a surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders—particularly birds—move in to take advantage. The production of nutrients peaks and falls away quickly, but the surge of new growth endures for some time. This makes floodplains particularly valuable for agriculture. Riparian zone species have significant differences from those that grow outside of floodplains. For instance, riparian trees tend to be very tolerant of root disturbance and tend to be very quick-growing compared to non-riparian trees.

9.2.1 Effects of Human Activities

Human activities tend to concentrate in floodplains for a number of reasons: water is readily available; land is fertile; transportation by water is easily accessible; and land is flatter and easier to develop. But human activity in floodplains frequently interferes with natural processes. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development creates local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream's capacity to contain flows; and it increases flow rates or velocities downstream during all stages of a flood event.

9.2.2 Federal Programs Related to Flooding

National Flood Insurance Program

The National Flood Insurance Program, or NFIP, makes federally backed flood insurance available to homeowners, renters, and business owners in communities participating in the program. For most communities participating in NFIP, FEMA has prepared a detailed Flood Insurance Study. The study presents water surface elevations for floods of various magnitudes, including the 1-percent annual chance flood (also called the 100-year flood or base flood) and the 0.2-percent annual chance flood (also called the 500-year flood). The water surface elevation of the 100-year flood event is called the base flood elevation. Base flood elevations and the boundaries of the 100- and 500-year floodplains are shown on participating communities' Flood Insurance Rate Maps, or FIRMs.

King County entered the NFIP on September 29, 1978. The county's currently effective FIRM is dated April 19, 2005. As a participant in the NFIP, the county must, at a minimum, regulate development in its floodplain areas in accordance with NFIP criteria. Before issuing a permit to build in a floodplain, the county must ensure that two criteria are met:

- New buildings and developments undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the 100-year flood.
- New floodplain developments must not aggravate existing flood problems or increase damage to other properties.

Structures permitted or built in the county before the effective date of the county's original FIRM (September 1978) are called "pre-FIRM" structures.

Although the King County Flood Control District is not a participant in the NFIP, implementation of district programs and policies will directly support King County's compliance and good standing under the NFIP.

The Community Rating System

The CRS is a voluntary incentive program that offers discounted flood insurance premiums to encourage floodplain management activities beyond the minimum NFIP requirements. CRS class ratings are assigned to participating communities based on 18 activities in the following categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Flood preparedness.

Insurance rates for property owners in participating communities are discounted in 5-percent increments, between a 5-percent discount for Class 9 communities and a 45-percent discount for Class 1 communities. The 1,100 communities participating in the CRS represent a significant portion of the nation's flood risk; over 66 percent of the NFIP's policy base is located in these communities.

King County has participated in the CRS since December 15, 1990 and is currently the nation's highest rated county. The county achieved its current CRS rating of Class 2 on October 1, 2007. This classification provides flood insurance policy holders up to a 40-percent reduction in flood insurance premiums and represents an estimated savings of $741,962 in annual premiums.

Although the King County Flood Control District is not a participant in the CRS, implementation of district programs and policies will directly support King County's CRS classification status. Many district programs also benefit cities in King County that participate in the CRS program.

9.3 HAZARD PROFILE

King County's floodplains reflect a geologic past that includes large-scale tectonic and volcanic processes that occurred over tens of millions of years, a period of extensive glaciation that ended about 15,000 years ago (Booth et al. 2003), and at least one major mudflow, the Osceola Mudflow, which occurred roughly 5,700 years ago. The tectonic and volcanic processes created large-scale landforms, such as the Cascade and Olympic Mountain ranges, the Olympic Peninsula and Puget Sound. The more recent glaciers and mudflows shaped many of the lowland surface features apparent today, including the topography and soils of King County's lowland river valleys. The Osceola Mudflow, which occurred when a flank of Mount Rainier collapsed, released sediment that filled the White River Basin to a depth of 75 feet and eventually settled in the lower Green River valley, converting it from an arm of Puget Sound to the fertile, low-gradient valley that it is today (Booth et al. 2003). These processes and events influenced the length, width, steepness, and sediment load and channel forms of King County's large rivers.

The headwaters and middle reaches of rivers in King County are typically steep and dominated by bedrock and boulders. In these areas, floodplains are often narrow or absent. When these rivers eventually reach the Puget Sound lowlands however, they flatten out, deposit sediments, and form floodplains that are often broad, ecologically complex and biologically productive.

In the relatively brief time since Euro-American settlement began in the Puget Sound basin, the region's floodplains have been altered extensively by development. Initially these changes were caused by land clearing and installation of drainage systems that supported land uses such as farming, mining and railroad transportation. Despite the relatively small population of settlers in the region, major changes occurred at an accelerating pace, including conversion of forested and vegetated floodplains to farmland, removal of woody debris from stream and river channels, channelization and bank armoring, rerouting of major rivers, and the construction of dams for water supply, flood control or hydropower.

These activities changed, often radically, the nature of King County rivers. The filling or disconnection of river side channels caused substantial losses of floodwater conveyance and habitat. Bank stabilization, typically using large, angular rock, reduced or eliminated natural riparian structures. Channel roughness was reduced and erosive water velocities increased. Large dams reduced peak flood flows and disrupted the natural flow of sediment and woody debris. Cumulatively, these actions changed many miles of rivers from hydraulically complex, multiple-thread or braided channels to higher-energy, flume-like, single-thread channels, sometimes in a matter of years. More recently, intensive residential, commercial and industrial land uses have come to occupy the downstream portions of King County's river valleys, exacerbating floodplain management conflicts and costs. It is in these flat, lowland floodplain areas that human development and flooding coincide, posing some of the greatest management challenges.

9.3.1 Principal Flooding Sources

King County can be segregated into six drainage basins, as described in the following sections.

South Fork Skykomish River Basin

The South Fork Skykomish River basin lies primarily in the northeast portion of King County and is a part of Water Resource Inventory Area 7. The King County portion of the South Fork Skykomish drains 234 square miles of mountainous terrain within the forest production zone and Alpine Lakes Wilderness Area. Major tributaries within King County include the Foss, Tye, Miller, and Beckler Rivers. There are no significant dams or reservoirs on the South Fork Skykomish or its tributaries. With its steep upper basin slopes in high elevation terrain forming the entire watershed, significant runoff can be delivered directly to the flood hazard management corridor along the South Fork Skykomish. Precipitation at these high elevations can generate flooding from rain-on-snow events.

Snoqualmie River Basin

The Snoqualmie River basin covers northeast King County and drains to the Snohomish River and ultimately to Puget Sound. It is a part of Water Resource Inventory Area 7. The watershed includes the Tolt River, the Raging River, Tokul Creek, Griffin Creek, Harris Creek, Patterson Creek and other tributaries. With the geologic segmentation of Snoqualmie Falls, the Snoqualmie River basin can be divided into two components; the Upper Snoqualmie and the Lower Snoqualmie.

Upper Snoqualmie River

There are no significant dams on the upper Snoqualmie River to regulate flood flows. All three forks of the Snoqualmie River are relatively steep and confined through most of their course upstream of the confluence area. The combination of no flood control impoundments and steep, confined upstream channels that open to lower-gradient floodplains makes creates widespread risk of inundation and channel migration during winter. Rain-on-snow events can have a significant effect in this unregulated system with headwaters in the high elevations of the Cascades.

Lower Snoqualmie River

With headwaters and much of the eastern basin in the Cascades and a drainage area of about 600 square miles at Carnation, the lower Snoqualmie River typically responds to winter rains with flood levels that rise and fall slowly and steadily. The low-gradient channel of the lower Snoqualmie meets the relatively steeper and faster-responding Skykomish River in Snohomish County, which can result in Skykomish River backwater influencing the lower Snoqualmie as far upstream as Duvall.

Sammamish River Basin

The Sammamish River originates at Lake Sammamish and drains a 240-square-mile watershed that includes 97 square miles of the Lake Sammamish basin, 50 square miles in the Bear Creek basin and 67 square miles of the combined Little Bear, North, and Swamp Creek basins. Water from the Lake Sammamish basin originally flowed into Lake Washington through the old Sammamish Slough, a widely meandering, low-gradient river bordered by extensive wetlands and floodplains. When Lake Washington was lowered by 9 feet after construction of the Lake Washington Ship Canal in 1912, property owners along the slough formed a drainage district to straighten and deepen the channel in order to reclaim the adjacent lands for agriculture. The U.S. Army Corps of Engineers completed river channelization in 1966 and constructed a low weir at the outlet of Lake Sammamish. The weir outlet slows release from Lake Sammamish during low-flow periods. During high flows, the weir is completely submerged by the river, acting as an uncontrolled spillway. The project was designed to pass approximately a 40-year springtime flood, equivalent to a 10-year winter storm, over the weir without the water surface elevation in Lake Sammamish exceeding 29.0 feet. The project has significantly reduced the frequency and severity of flooding risks around the lake and adjacent to the river.

Cedar River Basin

The Cedar River flows west and north from the Cascade Mountains into the south end of Lake Washington. The Cedar River is approximately 36 miles long from its mouth at Lake Washington in the City of Renton to Chester Morse Lake.

The hydrology and hydraulics of the Cedar River basin have been substantially altered from natural conditions. The lowest mile of the river was rerouted by the U.S. Army Corps of Engineers in 1914 in order to provide additional water for operation of the locks between Lake Washington and Puget Sound. The mouth of the Cedar River, which previously drained to the Black River and subsequently the Green River and into Puget Sound, was diverted into Lake Washington through a straightened, dredged channel with rock-stabilized banks. In the upper Cedar River watershed, the City of Seattle operates three dams designed for municipal water supply and hydropower purposes: the Masonry Dam, the reconstructed Crib Dam or Overflow Dike, and the Landsburg Diversion.

The first dam on the Cedar River was the rock-fill, timber-structured Crib Dam, constructed in 1903 and rebuilt as the Overflow Dike in 1987, at the outlet of what is now Chester Morse Lake. Masonry Dam controls storage capacity in Chester Morse Lake and the outflows used to produce hydroelectric power. Eleven miles farther downstream is the Landsburg Diversion, constructed in 1899, which diverts municipal and industrial water supply for the City of Seattle. The Masonry Dam was not designed or built to serve as a flood control dam, but in addition to its hydropower generation and water supply functions, it has the capacity to store up to 15,000 acre-feet of floodwater. However, flood-prone areas downstream remain vulnerable to severe flood risks.

Green River Basin

The Green/Duwamish River is a 93-mile long river system that originates in the Cascade Mountains at an approximate elevation of 4,500 feet and is entirely within King County. The headwaters are in the vicinity of Blowout Mountain and Snowshoe Butte, about 30 miles northeast of Mount Rainier. The river basin is part of Watershed Resource Inventory Area 9. The river flows through several cities, including Auburn, Kent, Renton, Tukwila and Seattle. The basin is divided into four subbasins: the upper watershed above Howard Hanson Dam; the middle Green; the lower Green; and the Duwamish estuary.

The middle Green River runs from the outlet of the Green River Gorge at about River Mile 45 near Flaming Geyser down to Auburn at about River Mile 31. The lower Green River runs from Auburn down to the Duwamish River at River Mile 11.

Major structural flood risk reduction features along the Green River include Howard Hanson Dam in the upper watershed and the levee system that lines the riverbanks along much of the lower Green River and portions of the middle Green River. Howard Hanson Dam and the levee system combine to reduce flooding in the lower river to a fraction of its historical magnitude. The dam is designed to store over 100,000 acre-feet, converting large storm flows to a flow at the Auburn flow gage equivalent to the 2-year pre-dam event—12,000 cubic feet per second (cfs). The capacity of the leveed portion of the river is approximately 12,800 cfs, with approximately 2 feet of freeboard in most locations.

Since 1962, dam operations, in combination with the levees, have contained most major river flood events from Auburn downstream to the mouth of the Duwamish River. Prior to construction of the dam, the river exceeded the target 12,000 cfs 15 times between 1932 and 1962. It is estimated that without the dam, the flows on the Green River would have exceeded this flood threshold 17 to 22 times since 1962.

White River Basin

The White River originates in the glaciers on the northeast face of Mount Rainier. The White River drains an area of about 490 square miles, approximately 30 percent of which lies within King County. The White River flows from its headwaters to the northwest, where it is joined by its major tributaries, the Greenwater River and Boise Creek. It then turns south to join with the Puyallup River in Pierce County, which flows to its outlet in Puget Sound at Commencement Bay.

Historically, the bulk of what is now the lower White River flowed northward to the join the Green River near Auburn. By the early 1900s legal intervention resulted in an Inter-County agreement and permanent diversion of the White River to flow south to the Stuck River and the Puyallup.

Mud Mountain Dam is a flood control dam near River Mile 30 that has had significant effect on flooding in the White River since its completion in 1948. Puget Sound Energy's diversion of flows since 1912 for hydropower generation through Lake Tapps at River Mile 244 has an effect on lower flows to the overall White River flow regime, although the effect has been insignificant with regard to flood magnitudes.

Above the dam, the entire watershed is largely undeveloped, although it includes some scattered residential and commercial property around the community of Greenwater. The river then flows through the White River canyon, a deep and generally undeveloped valley on the county line, and portions of the Muckleshoot Indian Tribe Reservation. Development generally is concentrated in the downstream end of the basin, where both industrial and residential land uses are common.

With headwaters on Mount Rainier glaciers, the White River experiences flow increases from snowmelt in late summer, but not to a level of flood concern. The primary determinant for flooding in the White River is operation of Mud Mountain Dam. The River basin is part of Water Resource Inventory Area 10.

9.3.2 Past Events

Generally, floods in King County occur every two to five years. In past floods, water depths have exceeded 6 feet above grade in some residential areas. Table 9-1 lists severe flood events in King County by basin since the 1990 event, which is considered to be the flood of record for most of the county except along the Lower Snoqualmie and Tolt Rivers.

9.3.3 Flooding Extent and Location

Flooding in King County has been documented by gage records, high water marks, damage surveys and personal accounts. This documentation was the basis for the April 19, 2005 Flood Insurance Study that is incorporated in the currently effective FIRMs. The FIRMs are the most detailed and consistent data source available for determining flood extent. The 2005 Flood Insurance Study is the sole source of data used in this risk assessment to map the extent and location of the flood hazard, as shown in Map 9-1.

9.3.4 Frequency

King County averages one episode of minor river flooding each winter. Large, damaging floods typically occur every two to five years. Urban portions of the county annually experience nuisance flooding related to drainage issues. Floods are commonly described as having 10-, 50-, 100-, and 500-year recurrence intervals, meaning that floods of these magnitudes have a 10-, 2-, 1-, or 0.2-percent chance, respectively, of occurring in any given year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. Recurrence intervals are different on different rivers. For example, the 1990 flood event was a 100-year flood on the Snoqualmie River at Snoqualmie, but a 50-year flood on some tributaries.

TABLE 9-1.
KING COUNTY FLOOD EVENTS BY BASIN

Date	Declara-tion #	Flood Phase[a]	Peak Flow[b]	Type of Damage	Estimated Damage Cost
South Fork Skykomish River Basin					
11/26/1990	#883	—	102,000	Overbank flooding causing damage to both public and private property. Stream bank erosion.	$1.4 million for entire county
02/19/1995	None	—	44,100	Overbank flooding.	No significant property damage reported
12/03/1995	#1079	—	79,600	Overbank flooding causing damage to both public and private property. Levee damage.	$ 1,141,498 in public property damage
02/10/1996	#1100	—	74,400	Overbank flooding causing damage to both public and private property. Stream bank erosion. Levee damage.	$215,142 in public property damage
10/20/2003	#1499	—	86,500	Public property damage only.	No Information Available
11/6/2006	#1671	—	129,000	Overbank flooding causing damage to both public and private property. Channel avulsion. Levee damage.	No Information Available
1/8/2009	#1817	—	69,500	Overbank flooding causing damage to both public and private property. Channel avulsion. Levee damage.	No Information Available
Snoqualmie River Basin					
01/10/1990	#852	IV	48,522	Overbank flooding causing damage to both public and private property. Channel avulsion.	$4.9 million for entire county
11/1990	#883	IV	50,100	Overbank flooding causing damage to both public and private property. Channel avulsion.	$5.6 million for entire county
11/7/1995	#1079	IV	49,350	Overbank flooding causing damage to both public and private property. Channel avulsion.	$ 683,612 in public property damage
01/1996	#1100	IV	44,430	Overbank flooding causing damage to both public and private property. Channel avulsion.	$1,598,304 in public property damage
01/1997	#1159	III	>20,000	Overbank flooding causing damage to both public and private property. Channel avulsion.	No information available
03/1997	#1172	III	>20,000	Overbank flooding causing damage to both public and private property. Channel avulsion.	$647,005

a. Flood phase as defined in King County Flood Warning Program (see Table 9-3)
b. Peak flow values listed in cubic feet per second (cfs), from the following gages, except as noted:
- South Fork Skykomish, USGS Gage 12134500
- Snoqualmie River, sum of the three Snoqualmie forks
- Sammamish River Basin (Issaquah Creek), USGS Gage 12120600
- Cedar River, USGS Gage 12117500
- Green River, USGS Gage 12113000
- White River, USGS Gage 12098500

**TABLE 9-1 (continued).
KING COUNTY FLOOD EVENTS BY BASIN**

Date	Declaration #	Flood Phase[a]	Peak Flow[b]	Type of Damage	Estimated Damage Cost
Snoqualmie River Basin (continued)					
10/1997	None	III	>20,000	No significant damage reported to public or private property.	
11/1999	None	IV	>38,000	Overbank flooding. No major damage to public or private property reported	
12/2000	None	III	>20,000	No significant damage reported to public or private property.	
01/2003	None	III	>20,000	No significant damage reported to public or private property.	
03/2003	None	III	>20,000	No significant damage reported to public or private property.	
1/18/2005	None	III	37,100	No significant damage reported to public or private property.	
1/10/2006	None	II	18,000	No significant damage reported to public or private property.	
11/7/2006	#1671	IV	55,000	Overbank flooding causing damage to both public and private property. Channel avulsion. Levee damage.	No Information Available
12/3/2007	#1734	III	23,100	Overbank flooding causing damage to both public and private property. Channel avulsion. Levee damage.	No Information Available
11/12/2008	None	IV	45,200	No significant damage reported to public or private property.	
1/9/2009	#1817	IV	60,700	Overbank flooding causing damage to both public and private property. Channel avulsion. Levee damage.	No Information Available
Sammamish River Basin					
12/1/1995	#1079	IV	1,240	Overbank flooding causing both public and private property damage within the Issaquah Creek Basin.	$5.2 million for entire county
01/1997	None	IV	1,240	Flooded farmland. No reports of significant public or private property damage.	No information available
Cedar River Basin					
01/09/1990	None	IV	5,308	Landslides and road damage due to flooding on small streams	Information not available
11/22/1990	#883	IV	10,800	Overbank flooding causing damage to both public and private property. Levee failure	$1.4 million for entire county

a. Flood phase as defined in King County Flood Warning Program (see Table 9-3)
b. Peak flow values listed in cubic feet per second (cfs), from the following gages, except as noted:
- South Fork Skykomish, USGS Gage 12134500
- Snoqualmie River, sum of the three Snoqualmie forks
- Sammamish River Basin (Issaquah Creek), USGS Gage 12120600
- Cedar River, USGS Gage 12117500
- Green River, USGS Gage 12113000
- White River, USGS Gage 12098500

TABLE 9-1 (continued).
KING COUNTY FLOOD EVENTS BY BASIN

Date	Declaration #	Flood Phase[a]	Peak Flow[b]	Type of Damage	Estimated Damage Cost
Cedar River Basin (continued)					
11/30/1995	#1079	IV	6,750	Overbank flooding causing damage to both public and private property.	$882,965 public property damage ($5.2 million for entire county
02/10/1996	#1100	IV	5,510	Overbank flooding causing damage to both public and private property. Levee failure	$1,385,193 in public property damage ($7.4 million for entire county
02/28/2001	#1361	—	—	Earthquake caused landslide that blocked the river at river mile 5, causing backwater flooding of public and private property.	Includes three home buyouts and replacement of Renton's spawning channel.
11/7/2006	#1671	IV	4,670	Overbank flooding causing damage to both public and private property. Levee failure	Information not available
1/7/2009	#1817	IV	7,870	Overbank flooding causing damage to both public and private property. Levee failure	Information not available
Green River Basin					
01/09/1990	None	III	10,800	No significant public or private property damage reported for this event	
11/09/1990	#883	III	10,200	Overbank flooding. Property damage to both public and private property. Levee damage.	$5.6 million for entire county
11/22/1990	#896	III	11,500	Overbank flooding. Property damage to both public and private property. Levee damage.	$1.4 million for entire county
02/19/1991	None	III	10,300	No significant public or private property damage reported for this event	
02/19/1995	None	III	9,450	No significant public or private property damage reported for this event	
12/01/1995	#1079	III	11,700	Overbank flooding. Property damage to both public and private property. Levee damage.	$2,402,374 in damage to public property
02/10/1996	#1100	IV	12,400	Overbank flooding. Property damage to both public and private property. Levee damage.	$1,728,704 in damage to public property

a. Flood phase as defined in King County Flood Warning Program (see Table 9-3)
b. Peak flow values listed in cubic feet per second (cfs), from the following gages, except as noted:
- South Fork Skykomish, USGS Gage 12134500
- Snoqualmie River, sum of the three Snoqualmie forks
- Sammamish River Basin (Issaquah Creek), USGS Gage 12120600
- Cedar River, USGS Gage 12117500
- Green River, USGS Gage 12113000
- White River, USGS Gage 12098500

TABLE 9-1 (continued).
KING COUNTY FLOOD EVENTS BY BASIN

Date	Declaration #	Flood Phase[a]	Peak Flow[b]	Type of Damage	Estimated Damage Cost
Green River Basin (continued)					
03/20/1997	#1172	III	9,290	No significant public or private property damage reported for this event	Information not available
12/1998	None	III	9580	No significant public or private property damage reported for this event	
11/26/1999	None	III	9,200	No significant public or private property damage reported for this event	
12/16/1999	None	III	9,130	No significant public or private property damage reported for this event	
11/7/2006	1671	IV	12,200	Overbank flooding. Property damage to both public and private property. Levee damage.	Information not available
1/7/2009	#1817	III	11,100	Overbank flooding. Property damage to both public and private property. Levee damage.	Information not available
White River Basin					
01/11/1990	None	IV	14,000	No significant public or private property damage reported for this event	
12/02/1995	#1079	IV	13,200	Overbank flooding. Property damage to both public and private property.	$304,054 in damage to public facilities
02/10/1996	#1100	III	10,600	Overbank flooding. Property damage to both public and private property.	$20,213 in damage to public facilities
12/30/1996	None	III	>8,000	No significant public or private property damage reported for this event	
11/6/2006	#1671	III	11,700 (estimated dam release)	Overbank flooding. Property damage to both public and private property.	Information not available
1/9/2009	#1817	III	11,700 (estimated dam release)	Overbank flooding. Property damage to both public and private property.	Information not available

a. Flood phase as defined in King County Flood Warning Program (see Table 9-3)
b. Peak flow values listed in cubic feet per second (cfs), from the following gages, except as noted:
- South Fork Skykomish, USGS Gage 12134500
- Snoqualmie River, sum of the three Snoqualmie forks
- Sammamish River Basin (Issaquah Creek), USGS Gage 12120600
- Cedar River, USGS Gage 12117500
- Green River, USGS Gage 12113000
- White River, USGS Gage 12098500

9.3.5 Severity

The severity of flooding is typically measured by the amount of damage it could cause. This can be evaluated by reviewing past flood damage estimates or by examining peak discharges used by FEMA in mapping the floodplains of King County. These are illustrated in Table 9-2.

TABLE 9-2.
KING COUNTY RIVER BASIN STREAM FLOW CHARACTERISTICS

	USGS Station	River Mile	Drainage Area (square miles)	100-Year Flow (cfs)	Flood of Record Date; Peak Flow (cfs)
South Fork Skykomish River					
Gold Bar	12134500	43.0	535	119,300	11/6/2006; 129,000
Snoqualmie River Basin					
North Fork	12142000	9.2	64.0	18,000	1/7/09; 17,100[d]
Middle Fork	12141300	55.6	154.0	37,100	11/6/2006; 31,700
South Fork	12143400	17.3	41.6	11,000	11/6/2006; 8,910
Snoqualmie @ Snoqualmie.	12144500	40.0	375	79,100	11/24/1990; 78,800
Snoqualmie @ Carnation	12149000	23	603.0	91,800	1/8/09; 83,400[c]
Raging @ Fall City	12145500	2.75	30.6	6,970	11/24/1990; 6,220
North Fork Tolt	12147500	11.7	39.9	11,200	12/15/1959; 9,560
South Fork Tolt	12148000	6.8	19.7	8,720	12/15/1959; 6,500
Tolt @ Carnation	12148500	8.7	81.4	18,800	1/8/09; 17,900[c]
Sammamish River Basin					
Sammamish River @ Mouth	12122000	5.6	99.6	4,300	1/1/1997; 2,870
Issaquah Creek @ Mouth	12121600	1.2	55.6	3,960	01/09/1990; 3,200
Cedar River basin					
Cedar Falls	12116500	33.2	84.2	8,030	11/24/1990; 12,300
Landsburg	12117500	23.4	121.0	10,300	11/18/1911; 14,200
Renton	12119000	1.6	184.0	12,000	11/24/1990; 10,600
Green River Basin					
Howard Hanson Dam	12105900	63.8	221.0	12,000[a]	12/21/1960; 12,200 (pre-dam)
Auburn	12113000	32.0	399.0	12,000[a]	11/23/1959; 28,100 (pre-dam)
Tukwila	12113350	NA	440.0	12,400	01/31/1965; 12,100
White River Basin					
Buckley	12098500	27.9	401.0	12,000[b]	12/01/1933; 28,000 (pre-dam)
Auburn	12100496	6.30	464.0	15,500	02/10/1996; 15,000
Greenwater	12097500	1.10	73.5	6,7870	12/02/1977; 10,500

a. Flows regulated by Howard Hanson Dam
b. Maximum release from Mud Mountain Dam
c. Provisional USGS data

9.3.6 Warning Time

Due to the extended precipitation needed to cause serious flooding, it is unusual for a flood to occur without warning. King County's flood-warning program warns of impending flooding on major rivers so residents and agencies can prepare before serious flooding occurs. In most locations, the warning system provides at least 2 hours of lead-time before floodwaters reach damaging levels. This is a phased warning program that has established response protocol for four phases of observed stream flow conditions:

- Phase I is an internal alert to King County staff.
- Phase II indicates minor flooding in some areas.
- Phase III indicates moderate flooding in some areas.
- Phase IV indicates major flooding in areas.

Flood phases indicate the severity of flooding and guide King County's response. Flood phases are issued independently for six major rivers. The thresholds for each phase are based on river gages that measure the flow and stage (depth) of the major rivers in various locations. Table 9-3 lists the peak flows by flood phase for each of the river basins for which the county provides warning.

TABLE 9-3.
FLOOD WARNING PHASE THRESHOLDS

	Threshold Flow (cfs) or Stage (feet)			
River Basin	Flood Phase I	Flood Phase II	Flood Phase II	Flood Phase IV
South Fork Skykomish	No warning time			
Snoqualmie (Sum of the Forks)	6,000 cfs	12,000 cfs	20,000 cfs	38,000 cfs
Tolt River (near Carnation)	1,500 cfs	2,500 cfs	4,500 cfs	7,000 cfs
Sammamish (Issaquah Creek near Hobart)	6.5 feet	7.5 feet	8.5 feet	9.0 feet
Cedar (at Landsburg)	1.000 cfs	2,800 cfs	3,500 cfs	4,200 cfs
Green (Actual or Expected Flow at Auburn)	5,000 cfs	7,000 cfs	9,000 cfs	12,000 cfs
White (Flow Released from Mud Mountain Dam)	5,000 cfs	8,000 cfs	10,000 cfs	12,000 cfs

9.4 SECONDARY HAZARDS

The most significant secondary hazard for flooding is bank erosion and rapid channel migration. In many cases, the threat and effects of bank erosion are worse than actual flooding. Flooding is also responsible for hazards such as landslides when high flows over-saturate soils on steep slopes, causing them to fail. Hazardous-material spills are also a secondary hazard of flooding if storage tanks rupture and spill into streams, rivers or drainage sewers.

9.5 CLIMATE CHANGE IMPACTS

There is a great diversity of views on the potential impacts of climate change on the flood hazard in the Pacific Northwest. For the purposes of this assessment, a worst-case scenario is assumed for considering climate-change-related impacts. An alternative view is that there would be no impact from climate change, but this assumption would not provide data useful for planning for future possibilities.

According to University of Washington scientists, global climate changes resulting in warmer, wetter winters are projected to increase flooding frequency in most Western Washington river basins. Future floods are expected to exceed the capacity and protective abilities of existing flood protection facilities, threatening lives, property, major transportation corridors, communities and regional economic centers.

Use of historical data has long been the standard of practice for designing and operating flood protection projects, developing flood forecasting models such as the National Weather Service’s River Forecast System Model, and forecasting snowmelt runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the relatively brief period of historical record. However, the historical hydrologic record cannot be used to predict increases in the frequency and severity of extreme events such as floods and droughts. Many experts have concluded the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climate events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

In light of these conclusions, model calibration and the statistical analyses used to set up models must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted.

Rising snowlines caused by climate change will allow additional mountain areas to contribute to peak storm runoff. High-frequency flood events may increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildland fires due to climate change, floods following fire could increase sediment loads and water quality impacts.

FEMA has traditionally used the 100-year flood event for federal flood insurance. As hydrology changes, the flow currently associated with a 100-year flood may occur more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, floodways, bypass channels and levees, as well as the design of local sewers and storm drains.

Some of the above information is taken from *Managing for an Uncertain Future, Climate Change Adaptation Strategies* (California Department of Water Resources, 2008). This document analyzes climate change impacts for the entire West Coast and is considered a regionally relevant document.

9.6 EXPOSURE

The Level 2 HAZUS-MH protocol was used to assess the risk and vulnerability to flooding in the planning area. HAZUS-MH uses census data at the block level and FEMA floodplain data, which has a level of accuracy acceptable for planning purposes. Where possible, the HAZUS-MH data for this risk assessment was enhanced using GIS data from county, state and federal sources.

9.6.1 Population

Population counts of those living in the floodplain within the planning area were generated by analyzing census blocks that intersect with the 100-year and 500-year floodplains identified on FIRMs. Census blocks do not follow the same boundaries as the floodplain. Therefore, the methodology used to generate these estimates evaluated census block groups whose centers are in the floodplain. Other census block groups were chosen in which the majority of the population most likely lives in or near the floodplain. HAZUS-MH estimated the number of buildings within the floodplain in each block, and then estimated the total population by multiplying the number of residential structures by the average King County household size of 2.39 persons per household.

Using this approach, it was estimated that the exposed population for the entire county is 22,535 within the 100-year floodplain (1.44 percent of the total county population) and 26,147 within the 500-year floodplain (1.7 percent of the total). For the unincorporated portions of the county, it is estimated that the exposed population is 7,794 within the 100-year floodplain (2.27 percent of the total unincorporated county population) and 8,387 within the 500-year floodplain (2.44 percent of the total).

9.6.2 Property

Structures in the Floodplain

Table 9-4 summarizes the number of structures in the floodplain by municipality. The HAZUS-MH model determined that there are 9,429 structures within the floodplain, or 1.13 percent of the total structures in the county. Thirty-five percent of these structures are in unincorporated areas. Sixty-two percent are residential, and 38 percent are commercial, industrial or agricultural.

Exposed Value

Table 9-5 summarizes the value of exposed buildings in the planning area as estimated by HAZUS-MH. This methodology estimated $10.08 billion worth of building-and-contents exposure to the 100-year flood, representing 3.08 percent of the total assessed value of the planning area, and $11.3 billion worth of building-and-contents exposure to the 500-year flood, representing 3.45 percent of the total.

Land Use in the Floodplain

South Fork Skykomish River Basin

The predominant land use in the South Fork Skykomish basin is forest use. Fifty percent of the basin is protected wilderness; 43 percent is zoned for forest production; 6 percent is in rural residential use; and 1 percent is in urban use. Development in the basin has been limited, but much of it has occurred in the floodplain. There are several developments in the Town of Skykomish, the unincorporated communities of Grotto and Baring and scattered residential subdivisions.

Snoqualmie River Basin

The major portion of the Snoqualmie River basin floodplain is in unincorporated King County, with small but significant portions in the cities of North Bend, Snoqualmie, Duvall and Carnation. Development throughout the incorporated portions of the Snoqualmie River floodplain is mainly commercial and residential. Agricultural and residential development predominates in unincorporated King County along the lower and upper portions of the river.

The cities of North Bend and Snoqualmie have significant residential development. During the January 2009 flood event, both cities suffered significantly from flood damage. Several structures in the City of Snoqualmie suffered substantial damage

TABLE 9-4.
STRUCTURES WITHIN 100-YEAR AND 500-YEAR FLOODPLAINS

	Number of Structures in Floodplain			Number of Structures in Floodplain	
	100-Year	500-Year		100-Year	500-Year
Algona	0	0	Newcastle	0	0
Auburn	346	346	Normandy Park	81	94
Beaux Arts	0	0	North Bend	818	1173
Bellevue	235	235	Pacific	37	63
Black Diamond	7	7	Redmond	196	223
Bothell	82	85	Renton	263	331
Burien	267	268	Sammamish	240	240
Carnation	85	502	SeaTac	6	6
Clyde Hill	0	0	Skykomish	171	171
Covington	87	87	Snoqualmie	628	628
Des Moines	125	125	Tukwila	74	74
Duvall	7	7	Woodinville	16	35
Enumclaw	0	0	Yarrow Point	0	0
Federal Way	92	92	Unincorporated:		
Hunts Point	0	0	Cedar River Basin	362	390
Issaquah	380	597	Green River Basin	419	419
Kenmore	118	132	Sammamish River Basin	238	301
Kent	1069	1069	Skykomish River Basin	196	196
Kirkland	12	12	Lower Snoqualmie River Subbasin	627	691
Lake Forest Park	35	35	Upper Snoqualmie River Subbasin	744	809
Maple Valley	0	0	White River Basin	182	210
Medina	0	0	Puget Sound Basin	493	493
Mercer Island	0	0	**Total**	**9,429**	**10,940**
Milton	0	5			

TABLE 9-5.
VALUE OF BUILDINGS WITHIN 100/500-YEAR FLOODPLAINS IN KING COUNTY

	Building/Contents Exposure Value				% of Total Assessed Value	
	100-year		500-year			
Municipality	Building	Contents	Building	Contents	100-Year	500-Year
Algona	$0	$0	$0	$0	0.000	0.000
Auburn	$244,168,500	$260,659,350	$244,168,500	$260,659,350	5.441	5.441
Beaux Arts	$0	$0	$0	$0	0.000	0.000
Bellevue	$108,611,300	$75,242,830	$108,611,300	$75,242,830	0.664	0.664
Black Diamond	$261,000	$136,500	$261,000	$136,500	0.084	0.084
Bothell	$380,780,700	$417,797,970	$380,877,700	$417,846,470	29.239	29.244
Burien	$106,395,100	$54,278,210	$106,395,100	$54,278,210	3.645	3.645
Carnation	$20,161,800	$12,203,580	$91,397,800	$49,289,380	13.121	57.037
Clyde Hill	$0	$0	$0	$0	0.000	0.000
Covington	$13,858,500	$7,267,950	$13,858,500	$7,267,950	1.028	1.028
Des Moines	$37,906,800	$27,171,480	$37,906,800	$27,171,480	1.972	1.972
Duvall	$2,294,700	$2,524,170	$2,294,700	$2,524,170	0.516	0.516
Enumclaw	$0	$0	$0	$0	0.000	0.000
Federal Way	$26,231,700	$13,533,450	$26,231,700	$13,533,450	0.376	0.376
Hunts Point	$0	$0	$0	$0	0.000	0.000
Issaquah	$149,405,200	$118,348,920	$434,996,800	$422,398,140	4.651	14.892
Kenmore	$26,443,800	$15,722,580	$28,913,800	$16,957,580	1.748	1.901
Kent	$1,816,502,229	$1,982,705,452	$1,816,502,229	$1,982,705,452	26.694	26.694
Kirkland	$6,592,400	$7,251,640	$6,592,400	$7,251,640	0.149	0.149
Lake Forest Park	$10,390,000	$5,398,400	$10,390,000	$5,398,400	0.875	0.875
Maple Valley	$0	$0	$0	$0	0.000	0.000
Medina	$0	$0	$0	$0	0.000	0.000
Mercer Island	$0	$0	$0	$0	0.000	0.000
Milton	$0	$0	$832,000	$416,000	0.000	2.650
Newcastle	$0	$0	$0	$0	0.000	0.000
Normandy Park	$24,969,000	$12,511,500	$28,940,000	$14,812,600	2.500	2.919
North Bend	$187,507,100	$147,525,010	$282,603,300	$200,899,830	42.863	61.858
Pacific	$5,867,000	$3,983,500	$9,414,000	$5,852,400	2.058	3.190
Redmond	$457,748,500	$500,670,350	$484,287,500	$529,863,250	7.758	8.209
Renton	$346,655,800	$368,864,780	$374,136,200	$394,416,820	5.691	6.113
Sammamish	$97,905,000	$49,339,500	$97,905,000	$49,339,500	1.698	1.698
SeaTac	$258,100	$207,110	$258,100	$207,110	0.013	0.013
Seattle	$220,834,815	$164,123,296	$243,203,815	$175,440,996	0.336	0.365
Shoreline	$4,319,000	$2,159,500	$6,574,000	$3,287,000	0.096	0.146
Skykomish	$17,471,200	$13,009,520	$17,471,200	$13,009,520	75.270	75.270
Snoqualmie	$167,489,200	$117,606,120	$167,489,200	$117,606,120	14.975	14.975

TABLE 9-5 (continued).
VALUE OF EXPOSED BUILDINGS WITHIN 100/500-YEAR FLOODPLAINS IN KING COUNTY

	Building/Contents Exposure Value				% of Total Assessed Value	
	100-year		500-year			
Municipality	Building	Contents	Building	Contents	100-Year	500-Year
Tukwila	$67,211,000	$73,219,900	$67,211,000	$73,219,900	2.964	2.964
Woodinville	$32,538,700	$35,792,570	$87,953,800	$96,670,580	2.722	7.354
Yarrow Point	$0	$0	$0	$0	0.00	0.00
Unincorporated:						
Cedar River Basin	$61,561,700	$30,394,070	$65,561,700	$33,394,070	0.781	0.841
Green River Basin	$76,706,600	$39,647,160	$76,706,600	$39,647,160	1.081	1.081
Sammamish River Basin	$89,551,200	$58,018,120	$104,551,200	$71,018,120	1.171	1.393
Skykomish River Basin	$25,236,600	$13,654,860	$25,236,600	$13,654,860	31.974	31.974
Lower Snoqualmie River Subbasin	$124,937,400	$70,004,940	$130,937,400	$73,004,940	3.861	4.039
Upper-Snoqualmie River Subbasin	$157,803,400	$86,883,140	$181,803,400	$98,883,140	15.323	17.578
White River Basin	$21,772,400	$11,006,160	$25,772,400	$13,006,160	2.382	2.818
Puget Sound Basin	$95,360,100	$53,034,510	$95,360,100	$53,034,510	3.765	3.765
Total	**$5,233,707,544**	**$4,851,898,098**	**$5,883,606,844**	**$5,413,345,588**	**3.080**	**3.450**

Sammamish River Basin

In recent decades, substantial development has occurred in the Sammamish River basin. Extensive commercial and residential developments have been constructed throughout the floodplain. There are also several parks and other recreational facilities. Land uses in the upper 10 miles are mainly recreational and agricultural as well as urban commercial, specifically in the Cities of Redmond and Woodinville. The lower 5 miles includes significant residential and commercial development as well as some open space.

Cedar River Basin

Land use in the upper Cedar River basin is dominated by forest uses (60.6 percent of the basin). The main uses in the lower basin are residential; 21.3 percent can be classified as low-density development, 7.7 percent as medium and 0.9 percent as high-density development. High-density development is located primarily in the Cities of Renton and Maple Valley. Damage in the City of Renton during the November 1990 flood was estimated to be $5 million. However, flood-prone areas of Maple Valley are largely in the unincorporated areas.

Green River Basin

Land use in the Green River basin varies significantly among the lower, middle and upper portions. The land in the upper Green River is primarily forestland. The middle Green River is primarily farmland and a mix of urban and rural residential. The major land uses are residential (50 percent), forestry (27 percent) and agriculture (12 percent) (King County 2005). Several large state and county parks abut the river in this segment. The lower Green River contains less farmland and is mainly urban. Except for occasional stretches of parkland, a mixture of residential, commercial and industrial land uses are the main land uses. Residential development (50 percent), industrial development (17 percent), and commercial development (10 percent) are the primary uses along the lower Green River.

White River Basin

Approximately 175 square miles in the White River basin is owned and managed by the Mount Baker-Snoqualmie National Forest. Another 90 square miles of the basin is part of Mount Rainier National Park. In this upper portion, the basin is mainly undeveloped but includes some scattered residential and commercial property around Greenwater (King County 1993). In the lower areas of the basin, there are some agricultural lands and a mix of residential, commercial and industrial uses closer to and in the cities. Upstream of the Muckleshoot Indian Reservation, the river is unconstrained and the valley is mostly undeveloped.

9.6.3 Critical Facilities and Infrastructure

Critical facilities are those buildings and infrastructure that must remain operable during hazard events to maintain essential services. Roads or railroads that are blocked or damaged can prevent access and can isolate residents and emergency service providers. Bridges washed out or blocked by floods or debris from floods also can cause isolation. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing waste to spill into homes, neighborhoods, rivers and streams. Underground utilities can also be damaged during flood events.

Tables 9-6 and 9-7 summarize the critical facilities and infrastructure in the floodplains of King County. Map 9-1 shows critical facility locations. Additionally, all of the over 500 facilities that the King County Flood Control District maintains, except for the flood warning center, are considered to be exposed to the flood hazard.

9.6.4 Environment

Flooding is a natural event, and floodplains provide many natural and beneficial functions. Nonetheless, with human development factored in, flooding can impact the environment in negative ways. Migrating fish can wash into roads or over levees into flooded fields, with no possibility of escape. Roadway pollutants and other hazardous materials can wash into rivers and streams. During floods, these can settle onto normally dry soils, polluting them for agricultural uses. Human development such as bridge abutments and levees, and channel obstructions can increase stream bank erosion, causing rivers and streams to migrate into non-natural courses. Floodplains often interface with critical habitat of threatened or endangered aquatic species such as salmon or bull trout. Impacts on the floodplains can have significant impacts on these species.

With 62 percent of the floodplain in unincorporated King County currently in an open space use, the county has taken significant steps to preserve the natural and beneficial functions of the floodplain, while at the same time reducing the risk of exposure to the built environment.

9.7 VULNERABILITY

9.7.1 Population

A geographic analysis of demographics, using the HAZUS-MH model and data obtained from the U.S. Census Bureau and Dun & Bradstreet, identified populations vulnerable to the flood hazard as follows:

- **Economically Disadvantaged Populations**—It is estimated that 3 percent of the people within the 100-year floodplain are economically disadvantaged, defined as having household incomes of $10,000 or less.

TABLE 9-6.
CRITICAL FACILITIES WITHIN THE KING COUNTY FLOODPLAIN

	Number of Critical Facilities in Floodplain	
	100-Year	500-Year
Medical and Health Services	1	1
Government Function	5	5
Protective Function	12	13
Schools	27	28
Societal Function	0	0
Hazmat	67	68
Other Critical Function	22	26
Total	**134**	**141**

TABLE 9-7.
CRITICAL INFRASTRUCTURE WITHIN THE KING COUNTY FLOODPLAIN

	Number of Critical Facilities in Floodplain	
	100-Year	500-Year
Water Supply	0	0
Wastewater	1	2
Power	0	0
Fuel storage	0	0
Communications	0	0
Bridges	152	164
Total	**153**	**166**

- **Population over 65 Years Old**—It is estimated that 4.2 percent of the population in the census blocks that intersect the 100-year floodplain are over 65 years old. Approximately 5 percent of the over-65 population in the floodplain also have incomes considered to be economically disadvantaged and are considered to be extremely vulnerable.
- **Population under 14 Years Old**— It is estimated that 7.7 percent of the population within census blocks located in or near the 100-year floodplain are under 14 years of age.

HAZUS estimated that a 100-year flood would displace 32,428 people, with 27,054 of those people needing short-term shelter. For a 500-year event, HAZUS estimated that 36,543 people would be displaced, with 30,806 needing short-term shelter.

9.7.2 Property

The HAZUS-MH program calculates losses to structures from flooding by looking at depth of flooding and type of structure. Using historical flood insurance claim data, HAZUS-MH estimates the percentage of damage to structures and their contents by applying established damage functions to an inventory. This inventory comes pre-loaded in the HAZUS-MH model and is based on data from the U.S. Census, state databases, the U.S. Highway Administration, and other sources. Default values can be overridden with locally generated data if available. For this analysis, local data on facilities was used to assess flood risk.

The analysis is summarized in Tables 9-8 and 9-9 for the 100-year and 500-year flood events, respectively. It is estimated that there would be up to $2.03 billion of flood loss from a 100-year flood event within the planning area. This represents 20.13 percent of the total exposure to the 100-year flood and 0.6 percent of the total assessed value for the county. It is estimated that there would be $2.52 billion of flood loss from a 500-year flood event, representing 22.3 percent of the total exposure to a 500-year flood event and 0.77 percent of the total assessed value.

TABLE 9-8.
ESTIMATED FLOOD LOSS FOR THE 100-YEAR FLOOD EVENT

	Estimated Flood Loss			% of Total Assessed Value
	Buildings	Contents	Total	
Algona	$0	$0	$0	0
Auburn	$45,514,000	$81,689,000	$127,203,000	1.371
Beaux Arts	$0	$0	$0	0
Bellevue	$4,617,000	$5,545,000	$10,162,000	0.04
Black Diamond	$0	$0	$0	0
Bothell	$37,641,000	$81,060,000	$118,701,000	4.35
Burien	$46,000	$56,000	$102,000	0.002
Carnation	$5,974,000	$6,880,000	$12,854,000	5.2
Clyde Hill	$0	$0	$0	0
Covington	$45,000	$54,000	$99,000	0.005
Des Moines	$212,000	$136,000	$348,000	0.011
Duvall	$1,033,000	$2,096,000	$3,129,000	0.34
Enumclaw	$875,000	$1,331,000	$2,206,000	0.17
Federal Way	$0	$0	$0	0
Hunts Point	$0	$0	$0	0
Issaquah	$15,821,000	$25,531,000	$41,352,000	0.72
Kenmore	$2,158,000	$1,990,000	$4,148,000	0.17
Kent	$250,828,000	$602,286,000	$853,114,000	5.6
Kirkland	$222,000	$264,000	$486,000	0.01
Lake Forest Park	$0	$0	$0	0
Maple Valley	$0	$0	$0	0
Medina	$0	$0	$0	0
Mercer Island	$0	$0	$0	0
Milton	$0	$0	$0	0
Newcastle	$0	$0	$0	0
Normandy Park	$4,429,000	$2,986,000	$7,415,000	0.5

TABLE 9-8 (continued).
ESTIMATED FLOOD LOSS FOR THE 100-YEAR FLOOD EVENT

	Estimated Flood Loss			% of Total Assessed Value
	Buildings	Contents	Total	
North Bend	$21,562,000	$36,122,000	$57,684,000	7.4
Pacific	$1,373,000	$991,000	$2,364,000	0.49
Redmond	$29,709,000	$62,722,000	$92,431,000	0.75
Renton	$66,883,000	$147,987,000	$214,870,000	1.71
Sammamish	$2,762,000	$1,432,000	$4,194,000	0.048
SeaTac	$17,000	$34,000	$51,000	0.001
Seattle	$657,000	$443,000	$1,100,000	0.001
Shoreline	$0	$0	$0	0
Skykomish	$2,760,000	$4,100,000	$6,860,000	16.94
Snoqualmie	$17,432,058	$12,364,870	$29,796,928	1.57
Tukwila	$44,693,000	$82,886,000	$127,579,000	2.7
Woodinville	$3,779,000	$6,425,000	$10,204,000	0.41
Yarrow Point	$0	$0	$0	0
Unincorporated:				
Cedar R. Basin	$11,659,000	$7,846,000	$19,505,000	0.17
Green R. Basin	$32,464,000	$27,920,000	$60,384,000	0.56
Sammamish R. Basin	$8,289,000	$22,868,000	$31,157,000	0.25
Skykomish R. Basin	$5,304,000	$4,191,000	$9,495,000	7.81
Lower Snoqualmie R. Subbasin	$56,283,000	$43,041,000	$99,324,000	1.97
Upper-Snoqualmie R. Subbasin	$37,386,000	$25,161,000	$62,547,000	3.92
White R. Basin	$10,433,000	$9,405,000	$19,838,000	1.44
Puget Sound Basin[a]	$0	$0	$0	0
Total	**$716,750,833**	**$1,313,952,095**	**$2,030,702,928**	**0.6**

a. Values for flood loss for the Puget Sound Basin were not calculated due to the lack of detailed flood study information on the coastal flood zones in this region.

TABLE 9-9.
ESTIMATED FLOOD LOSS FOR THE 500-YEAR FLOOD EVENT

	Estimated Flood Loss			% of Total Assessed Value
	Buildings	Contents	Total	
Algona	$3,000	$2,000	$5,000	0.001
Auburn	$45,770,000	$81,721,000	$127,491,000	1.374
Beaux Arts	$0	$0	$0	0.000
Bellevue	$11,150,000	$14,063,000	$25,213,000	0.091
Black Diamond	$0	$0	$0	0.000
Bothell	$37,641,000	$81,060,000	$118,701,000	4.346
Burien	$102,000	$101,000	$203,000	0.005
Carnation	$12,648,000	$9,896,000	$22,544,000	9.140
Clyde Hill	$0	$0	$0	0.000
Covington	$45,000	$54,000	$99,000	0.005
Des Moines	$314,000	$203,000	$517,000	0.016
Duvall	$1,300,000	$2,463,000	$3,763,000	0.403
Enumclaw	$875,000	$1,331,000	$2,206,000	0.172
Federal Way	$0	$0	$0	0.000
Hunts Point	$0	$0	$0	0.000
Issaquah	$39,222,000	$66,769,000	$105,991,000	1.841
Kenmore	$5,540,000	$5,656,000	$11,196,000	0.464
Kent	$250,828,000	$602,286,000	$853,114,000	5.994
Kirkland	$748,000	$771,000	$1,519,000	0.016
Lake Forest Park	$0	$0	$0	0.000
Maple Valley	$0	$0	$0	0.000
Medina	$0	$0	$0	0.000
Mercer Island	$0	$0	$0	0.000
Milton	$0	$0	$0	0.000
Newcastle	$27,000	$17,000	$44,000	0.002
Normandy Park	$5,112,000	$3,439,000	$8,551,000	0.570
North Bend	$67,460,000	$96,772,000	$164,232,000	21.012
Pacific	$1,495,000	$1,080,000	$2,575,000	0.538
Redmond	$54,895,000	$126,998,000	$181,893,000	1.472
Renton	$71,468,000	$153,307,000	$224,775,000	1.788
Sammamish	$2,770,000	$1,434,000	$4,204,000	0.048
SeaTac	$20,000	$77,000	$97,000	0.003
Seattle	$3,000,000	$2,177,000	$5,177,000	0.005
Shoreline	$0	$0	$0	0.000
Skykomish	$3,843,000	$5,222,000	$9,065,000	22.385
Snoqualmie	$25,309,918	$53,783,575	$79,093,493	4.154

TABLE 9-9 (continued).
ESTIMATED FLOOD LOSS FOR THE 500-YEAR FLOOD EVENT

	Estimated Flood Loss			% of Total Assessed Value
	Buildings	Contents	Total	
Tukwila	$44,747,000	$82,955,000	$127,702,000	2.695
Woodinville	$5,959,000	$10,275,000	$16,234,000	0.647
Yarrow Point	$0	$0	$0	0.000
Unincorporated:				
Cedar R. Basin	$18,864,000	$12,579,000	$31,443,000	0.267
Green R. Basin	$32,535,000	$28,024,000	$60,559,000	0.563
Sammamish R. Basin	$19,743,000	$57,967,000	$77,710,000	0.617
Skykomish R. Basin	$7,833,000	$5,895,000	$13,728,000	11.286
Lower Snoqualmie R. Subbasin	$63,750,000	$48,065,000	$111,815,000	2.215
Upper-Snoqualmie R. Subbasin	$64,531,000	$42,971,000	$107,502,000	6.732
White R. Basin	$12,378,600	$11,473,800	$23,852,400	1.733
Puget Sound Basin[a]	$0	$0	$0	0
Total	**$911,926,518**	**$1,610,887,375**	**$2,522,813,893**	**0.770**

a. Values for flood loss for the Puget Sound Basin were not calculated due to the lack of detailed flood study information on the coastal flood zones in this region.

9.7.3 Critical Facilities and Infrastructure

HAZUS-MH was used to estimate the loss potential to critical facilities exposed to the flood risk. HAZUS uses depth/damage function curves to estimate the percent of damage to building and contents, then correlates these estimates to an estimate of functional downtime (the estimated time it will take to restore a facility to 100 percent of its functionality). No analysis of district critical facilities was performed due to the lack of established damage functions for levees, revetments and pump stations. Results for other critical facilities are as follows:

- **100-year flood event**—Critical facilities would receive 4.8 percent damage to the structure and 39.2 percent damage to the contents, and the estimated time to restore these facilities to full functionality would be 135 days.
- **500-year flood event**—Critical facilities would receive 7.9 percent damage to the structure and 49 percent damage to the contents, and the estimated time to restore these facilities to full functionality would be 409 days.

9.7.4 Environment

The environment vulnerable to flood hazard is the same as the environment exposed to the hazard. Loss estimation platforms such as HAZUS-MH are not currently equipped to measure environmental impacts of flood hazards. The best gauge of vulnerability of the environment would be a review of damage from past flood events. Loss data that segregates damage to the environment were not available at the time of this plan. Capturing this data from future events could prove to be beneficial in measuring the vulnerability of the environment for future updates.

9.8 FUTURE TRENDS IN DEVELOPMENT

South Fork Skykomish River Basin

The South Fork Skykomish River basin has maintained a rural land use environment. Significant development has not and likely will not occur in this area because a large portion of it is protected wilderness area and forest production area. Future land use is projected to be similar to current land use. Only a small increase in households is projected for the period through 2022 (King County 2004).

Snoqualmie River Basin

Much of the urbanization in the Snoqualmie River basin has been in incorporated areas. While urban areas constitute only about 3 percent of the basin, they make up a significant portion of some subbasins, including the main stem Snoqualmie (15 percent), Patterson Creek (10 percent), and Cherry Creek (6 percent). The potential for high-density development is increased by the presence of vested lots and plats, particularly in the Patterson and Ames Creeks areas.

Sammamish River Basin

The Sammamish River basin has been urbanizing rapidly since the 1950s. Future development is expected to continue throughout the basin. Bellevue, Kirkland and Redmond have designated potential annexation areas, some of which are within the floodplain.

Cedar River Basin

The greater part of the Cedar River floodplain is in unincorporated King County, with a smaller portion in the City of Renton. There is commercial, industrial and residential development throughout the incorporated areas of the Cedar River floodplain. Residential development has also occurred in unincorporated King County along the lower floodplain reaches, which is likely due to its proximity to Renton. Renton is expected to annex portions of the land along the Cedar River. There is expected to be a significant amount of growth in Renton by 2022 (King County 2005).

Green River Basin

The Green River basin has been urbanizing since the 1970s. In the 1990s, Black Diamond, Enumclaw and Covington experienced rapid growth. Land development estimates indicate that the largest areas of future development will be in the lower and middle Green River areas.

White River Basin

The majority of the White River basin is in unincorporated King County, with a smaller portion in the cities and the Muckleshoot Indian Tribe Reservation. There is commercial, industrial and residential development throughout the incorporated areas of the White River floodplain. The majority of development is along the White River in the Auburn and Pacific area. This area has significant potential for new residential, commercial and industrial development.

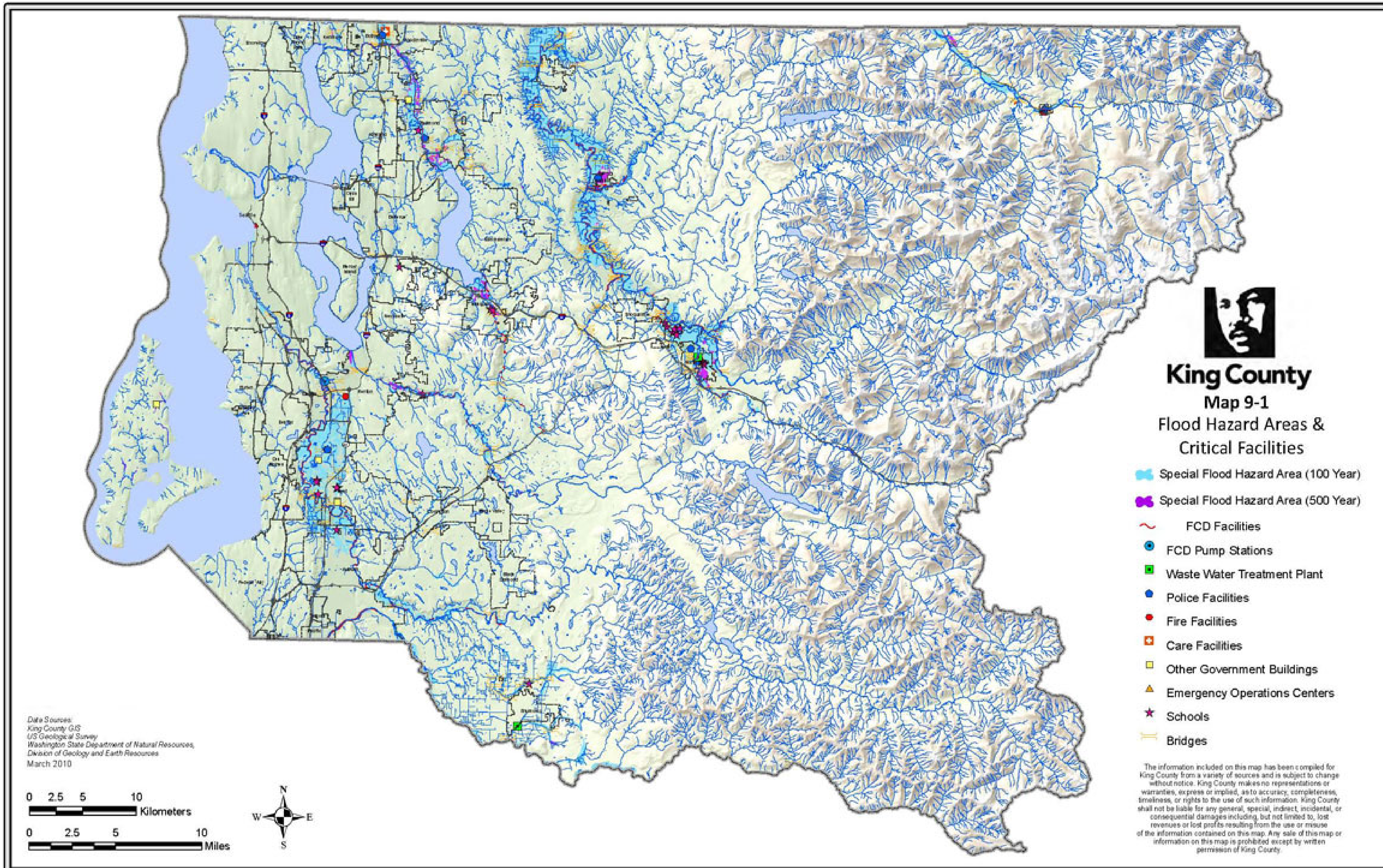
9.9 SCENARIO

Historically, floods have had significant impacts on King County Flood Control District facilities. The district can expect significant flooding every two to five years. The duration and intensity of the storms that cause flooding may increase due to climate change. The floodplains mapped and identified by King County will continue to take the brunt of these floods. County residents prepare themselves for flooding by being informed and by pursuing mitigation. The impacts of flood events should decrease as the county, the district and residents continue to promote and implement hazard mitigation and preparedness.

9.10 ISSUES

Important issues associated with flood hazards include but are not limited to the following:

- More information is need on flood risk to support the concept of risk-based analysis of capital projects.
- There needs to be a sustained effort to gather historical damage data such as high water marks on structures and damage reports to measure the cost-effectiveness of future mitigation projects.
- Ongoing flood hazard mitigation will require funding from multiple sources to continue.
- There needs to be a coordinated hazard mitigation effort between jurisdictions affected by flood hazards in the county.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods.
- The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.
- The concept of residual risk should be considered in the design of future capital flood control projects and should be communicated with residents living in the floodplain.


King County
Map 9-1
Flood Hazard Areas &
Critical Facilities
Special Flood Hazard Area (100 Year)
Special Flood Hazard Area (500 Year)
FCD Facilities
FCD Pump Stations
Waste Water Treatment Plant
Police Facilities
Fire Facilities
Care Facilities
Other Government Buildings
Emergency Operations Centers
Schools
Bridges
The information included on this map has been compiled for King County from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information. King County shall not be liable for any general, special, indirect, incidental, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
March 2010
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CHAPTER 10.
DAM FAILURE

10.1 DAM FAILURE DEFINED

The following definitions apply in the discussion of dam failure hazards:

- ***Dam***—Any artificial barrier or controlling mechanism that can impound 10 acre-feet or more of water.
- ***Dam Failure***—An uncontrolled release of impounded water due to structural deficiencies in the water barrier.
- ***High Hazard Dam***—dams whose failure would cause loss of human life.

10.2 GENERAL BACKGROUND

Dam failures can be catastrophic to human life and property downstream. Under the National Dam Safety Act (Public Law 92-367), the U.S. Army Corps of Engineers is responsible for safety inspections of federal and non-federal dams in the United States that meet the size and storage limitations specified in the act. The Corps has inventoried dams; surveyed each state and federal agency's capabilities, practices and regulations regarding the design, construction, operation and maintenance of the dams; developed guidelines for the inspection and evaluation of dam safety; and formulated recommendations for a comprehensive national program (U.S. Army Corps of Engineers, 1997).

The National Dam Safety Program requires a periodic, thorough engineering analysis of every major dam in the U.S. The goal of this FEMA-monitored effort is to identify and mitigate the risk of dam failure so as to protect the lives and property of the public. The Washington Department of Ecology's Dam Safety Office monitors the program at the state level. Dam failures typically occur as follows (see Figure 10-1):

- Overtopping of the primary dam structure, which accounts for 34 percent of all dam failures, can occur due to inadequate spillway design, settlement of the dam crest or blockage of spillways, and by other means.
- Foundation defects due to differential settlement, slides, slope instability, uplift pressures, and foundation seepage account for 30 percent of all dam failures.
- Failure due to piping and seepage accounts for 20 percent of all failures. These are caused by internal erosion due to piping seepage, erosion along hydraulic structures such as spillways, erosion due to animal burrows, and cracks in the dam structure.
- Failure due to conduit and valve problems, typically caused by the piping of embankment material into conduits through joints or cracks, constitutes 10 percent of all failures.
- The remaining 6 percent are due to other miscellaneous causes.

Many dam failures in the United States have been secondary results of other disasters, such as earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, or sabotage. The most likely disaster-related causes of dam failure in King County are earthquakes, overtopping caused by excessive rainfall, and landslides. Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies.

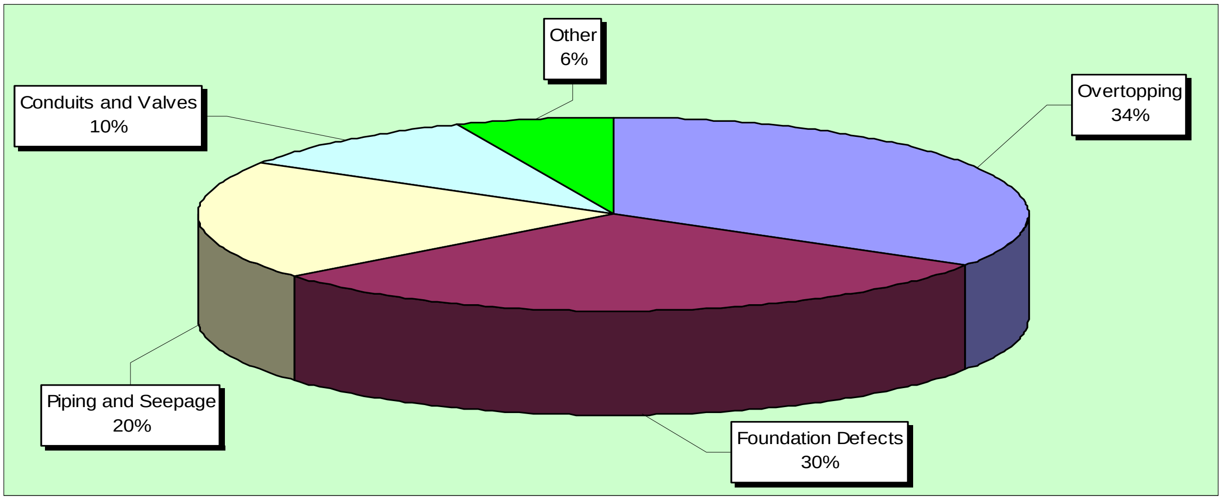


Figure 10-1. Historical Causes of Dam Failure

10.3 HAZARD PROFILE

10.3.1 Past Events

Recorded Failures

The Department of Ecology Dam Safety Office maintains records of dam accidents in Washington for structures impounding more than 10 acre-feet of water. Between 1918 and 2003, 15 notable dam failure events occurred in Washington. Three of these occurred in King County and resulted in 9 fatalities (see Table 10-1).

**TABLE 10-1.
NOTABLE DAM FAILURE INCIDENTS IN KING COUNTY**

Project Name	Location	Date	Lives Lost	Nature of Failure
Masonry Dam (Cedar River)	Near North Bend	12/22/1918	0	Excessive seepage through glacial moraine abutment caused mud flow about 1 mile from reservoir
Eastwick Railroad Fill Failure	Near North Bend	02/1932	7	Blockage of a culvert by a slide caused railroad fill to backup water and fail. This destroyed the railroad line and the village of Eastwick.
White River Incident	Near Auburn	07/1976	2	Surge in flow caused by increased discharge from Mud Mountain Dam and removal of flashboards at diversion dam. Two children playing in the White River were killed during this incident.

Howard Hanson Dam Restrictions

Howard Hanson Dam is located on the upper reach of the Green-Duwamish River in King County, 64 river miles above the mouth. It is in the city of Tacoma's municipal watershed 35 miles east of Tacoma, 6 miles upstream from Palmer, and 12 miles from Mud Mountain Dam. The dam is protected from public access. The Howard Hanson Dam provides both flood risk reduction and water storage for river flow regulation and municipal water supply. It also provides summer low flow augmentation for fish spawning. Flood risk reduction in the Green-Duwamish River Basin is accomplished by capturing excessive water runoff from the upper drainage area of the river and releasing the water under controlled conditions. After the end of the annual winter flood season, water is gradually stored in the reservoir beginning about 1 March. The stored water is used for municipal water supply and to augment the river flow for the benefit of fish.

Following a record high level of water behind Howard Hanson Dam in January 2009, the U.S. Army Corps of Engineers restricted flood storage behind the dam because of concerns about two depressions on the right abutment, increased water levels in groundwater monitoring wells, and the appearance of silty water entering the abutment drainage tunnel. Engineers have excavated the depressions, installed additional monitoring equipment and conducted tests while a summer pool was stored at the dam. Interim repairs made at Howard Hanson Dam in the summer of 2009 reduced the risk of flooding along the Green River from 1 in 3 prior to the repair to 1 in 25. The work included adding to a series of drainage tunnels and installing a grout curtain within the abutment.

While this circumstance does not constitute a dam failure, Howard Hanson Dam is being operated at a limited capacity. Downstream communities have increased their awareness of the short-term flood threat and longer term risks associated with high hazard dams.

10.3.2 Location

There are 87 dams in King County that impact 10 acre-feet or more of water. The Department of Ecology classified nine of these dams as having a high hazard potential (defined as a population at risk of more than 300) and 48 as having a low hazard potential (population at risk of zero). Table 10-2 lists the King County dams with high hazard potential and one dam in Snohomish County, the Culmback Dam, which has a significant inundation area within King County along the Lower Snoqualmie River.

King County has four major dams that would cause a countywide emergency if they should fail. These dams are located on the Tolt, Cedar, White, and Green rivers. Maps showing the potential inundation areas for these facilities should they fail have been prepared to support emergency response planning. These maps were used for risk assessment in this hazard mitigation plan, but are not included in the plan for security purposes.

Certain areas of King County would also be adversely affected by failures of the White River Project in Pierce County or the Jackson Project in Snohomish County. Additionally, localized problems could occur if one of the minor dams in the county failed.

10.3.3 Frequency

Dam failure events are infrequent; their frequency coincides with that of the events that may cause them, including earthquakes, landslides and excessive rainfall and snowmelt. Three notable dam failure incidents have occurred within King County since 1918.

10.3.4 Severity

Dam failure can be catastrophic to all life and property downstream. Past dam failure events in King County and Washington State have led to loss of life and have had significant economic and environmental impacts. Table 10-3 shows the U.S. Army Corps of Engineers' classification for determining hazard potential of dam failures (U.S. Army Corps of Engineers, 1995).

**TABLE 10-2.
HIGH CONSEQUENCE DAMS IN KING COUNTY**

Name	Hazard Class[a]	Water Course	Owner	Year Built	Dam Type	Crest Length (feet)	Height (feet)	Storage Capacity (acre-feet)	Drainage area (sq. mi.)
Beacon Hill South Reservoir	1A	Tr-East Waterway, Off-stream	Seattle Public Utilities	1911	Earth Fill	1,545	18	170	0.02
Green Lake Reservoir	1A	Tr-East Puget Sound, Off-stream	Seattle Parks and Recreation	1910	Earth Fill	1,920	25	181	0.02
Howard Hanson	1A	Green River-South	U.S. Army Corps of Engineers	1962	Earth Fill-Rock Fill	500	235	136,700	221
Issaquah Highlands Washington Department of Transportation Detention Pond	1A	Issaquah Creek	Port Blakely Communities	2008	Earth Fill	380	22	53	0.00
Maple Leaf Reservoir	1A	Tr-Puget Sound, Off-stream	Seattle Parks and Recreation	1910	Earth Fill	1,270	35	201	0.02
Masonry Dam	1A	Cedar River	City of Seattle	1914	Concrete Single Arch	980	225	175,000	81.40
Mud Mountain Dam	1A	White River	U.S. Army Corps of Engineers	1948	Rock Fill	700	425	156,000	400
Tolt River Dam	1A	South Fork Tolt River	Seattle Public Utilities	1962	Earth Fill	980	213	672,000	18.80
Youngs Lake Outlet Dam	1A	Little Soos Creek	City of Seattle	1921	Earth Fill	1,450	30	18,908	3.94
Culmback Dam	1A	Sultan River	Snohomish Co. PUD	1965	Rock Fill	480	270	200,000	74.50

a. Downstream Hazard Class 1A = Greater than 300 lives at risk

TABLE 10-3.
HAZARD POTENTIAL CLASSIFICATION

Category[a]	Direct Loss of Life[b]	Lifeline Losses[c]	Property Losses[d]	Environmental Losses[e]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

a. Categories are based upon project performance and do not apply to individual structures within a project.
b. Loss of life potential based upon inundation mapping of area downstream of the project. Analyses of loss of life potential should take into account the population at risk, time of flood wave travel, and warning time.
c. Indirect threats to life caused by the interruption of lifeline services due to project failure or operational disruption; for example, loss of critical medical facilities or access to them.
d. Damage to project facilities and downstream property and indirect impact due to loss of project services, such as impact on the navigation industry of the loss of a dam and navigation pool, or impact on a community of the loss of water or power supply.
e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond which would normally be expected for the magnitude flood event under which the failure occurs.

10.3.5 Warning Time

Warning time for dam failure varies depending on the cause of the failure. In events of extreme precipitation or anticipated massive snowmelt, evacuations can be planned with sufficient time. In the event of a structural failure due to earthquake, it is possible that there would be no warning time.

A dam’s structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections formed during dam construction are forced apart by the escaping water. The time for breach formation is in the range of a few minutes to a few hours (U.S. Army Corps of Engineers, 1997).

10.4 SECONDARY HAZARDS

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure include landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat.

10.5 CLIMATE CHANGE IMPACTS

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or all of its designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle to maintain the required margins of safety. These earlier releases of increased volumes can increase flood potential downstream.

Dams are constructed with spillways that allow controlled overflow if the reservoir fills too quickly. Spillway overflow events, often referred to as "design failures," result in increased discharges downstream and increased flooding potential. The impacts of climate change may increase the probability of design failures. Throughout the Pacific Northwest, communities downstream of dams are already seeing the impacts from climate change due to increases in stream flows from earlier releases from dams.

10.6 EXPOSURE

The flood module of HAZUS-MH was used for a Level 2 assessment of dam failure risk and vulnerability in the planning area. HAZUS-MH uses census data at the block level and FEMA floodplain data, which has a level of accuracy acceptable for planning purposes. Where possible, the HAZUS-MH data for this risk assessment was enhanced using GIS data from county, state and federal sources. The exposure and vulnerability analyses focused on the four principal dams of concern, which are on the Tolt, Cedar, White and Green Rivers.

10.6.1 Population

Failure at any of the major dams is likely to cause loss of human life. All populations within dam failure inundation zones would be exposed to the effects of a dam failure. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living in areas of potential inundation. The population within the dam-failure inundation areas along the Tolt, Cedar, Green and White Rivers is 64,846, or 3.4 percent of the total district population. Table 10-4 summarizes the at-risk population information.

TABLE 10-4.
POPULATION AT RISK FROM DAM FAILURE

River System	Affected Population	% of County
Tolt	3,134	0.16
Cedar	2,434	0.13
Green	27,089	1.42
White	32,189	1.69
Total	**64,846**	**3.4**

10.6.2 Property

The HAZUS-MH model used parcel data from the King County Assessor to estimate that there are 24,666 structures within the inundation areas, as summarized in Table 10-5. Forty-one percent of these structures are residential; the remaining 59 percent are commercial, industrial or agricultural.

TABLE 10-5.
NUMBER OF STRUCTURES IN THE DAM-FAILURE INUNDATION ZONE

River System	Affected Population	% of County	# of Structures
Tolt	3,134	0.16	1,192
Cedar	2,434	0.13	926
Green	27,089	1.42	10,304
White	32,189	1.69	12,244
Total	**64,846**	**3.4**	**24,666**

The value of exposed buildings in the planning area was generated using HAZUS-MH and is summarized in Table 10-6. This methodology estimated $31.5 billion worth of building-and-contents exposure to dam failure inundation, representing 9.64 percent of the total assessed value of the planning area.

TABLE 10-6.
VALUE OF PROPERTY EXPOSED TO DAM FAILURE

Jurisdiction	Building Value Exposed	Contents Value exposed	**Total Value Exposed**	% of Total Assessed Value
Algona	$432,899,600	$345,776,680	**$778,676,280**	74.47
Auburn	$4,481,774,800	$4,180,618,520	**$8,662,393,320**	55.46
Carnation	$140,550,600	$92,263,260	**$232,813,860**	94.39
Duvall	$14,422,700	$15,813,970.00	**$30,236,670**	3.24
Federal Way	$969,400	$954,740	**$1,924,140**	0.02
Kent	$5,908,992,684	$6,386,364,756	**$12,295,357,440**	63.14
Pacific	$510,276,300	$342,084,570	**$852,360,870**	94.43
Renton	$2,311,356,100	$2,503,575,110	**$4,814,931,210**	38.30
SeaTac	$854,000	$427,000	**$1,281,000**	0.02
Seattle	$37,294,100	$41,023,510	**$78,317,610**	0.06
Tukwila	$1,548,053,900	$1,692,305,890	**$3,240,359,790.00**	34.40
Unincorporated County	$353,451,800	$214,059,940	**$567,511,740.00**	1.34
Total	**$15,740,895,984**	**$15,815,267,946**	**$31,556,163,930**	**9.64**

Since the dam failure inundation areas overlie the mapped floodplain areas, the land use in these areas is the same as described for the flood risk assessment in Section 9.6.3.

10.6.4 Critical Facilities and Infrastructure

An exposure analysis was performed for all critical facilities defined under the King County Critical Areas Ordinance (King County Code 21A.06.260). Tables 10-7 and 10-8 summarize the critical facilities subject to possible inundation from dam failure. Although a detailed inventory of critical facilities in the planning area was created for this analysis, it is not included in this plan for security purposes.

**TABLE 10-7.
CRITICAL FACILITIES WITHIN
THE KING COUNTY DAM INUNDATION ZONE**

Medical and Health Services	4
Government Function	9
Protective Function	21
Schools	49
Societal Function	0
Hazmat	117
Other Critical Function	41
Total	**241**

**TABLE 10-8.
CRITICAL INFRASTRUCTURE WITHIN
THE KING COUNTY DAM INUNDATION ZONE**

Water Supply	0
Wastewater	1
Power	0
Fuel storage	0
Communications	0
Bridges	139
Total	**140**

10.6.5 Environment

The environment would be exposed to a number of risks in the event of dam failure. The inundation could introduce many foreign elements and debris into local waterways. This could result in destruction of downstream habitat and could have detrimental effects on many species of animals, especially endangered species such as salmon.

10.7 VULNERABILITY

10.7.1 Population

Vulnerable populations are all populations downstream from a dam failure that are incapable of escaping the area within the allowable time frame. This population includes the elderly and young who may be unable to get themselves out of the inundation area. The vulnerable population also includes those who would not have adequate warning from a television or radio emergency warning system.

10.7.2 Property

Vulnerable properties are those located closest to the dam inundation area. These properties would experience the largest, most destructive surge of water. Low-lying areas are also vulnerable since this is where dam waters would collect.

The initial vulnerability analysis for property used HAZUS-MH, which requires detailed mapping that illustrates depth of flooding. Such mapping was available only for the Culmback Dam and Tolt River Dam. Therefore, the property initial vulnerability analysis addresses only these two facilities. The analysis is summarized in Table 10-9.

TABLE 10-9.
VALUE OF PROPERTY EXPOSED TO DAM FAILURE

Jurisdiction	Source	Building Loss	Contents Loss	Total Loss	% of Total Exposure
Duvall	Culmback	$1,155,750	$2,091,750	$3,247,500	15.89
Unincorporated County	Culmback	$13,351,500	$8,952,000	$22,303,500	73.97
Carnation	Tolt	$91,298,000	$67,056,000	$158,354,000	68.02
Duvall	Tolt	$1,732,000	$3,160,000	$4,892,000	49.90
Unincorporated County	Tolt	$69,717,000	$45,647,000	$115,364,000	67.51
Total		**$177,254,250**	**$126,906,750**	**$304,161,000**	**55.06**[a]

a. This value represents the average percentage of the total exposure for each loss scenario.

HAZUS-MH estimated that there would be up to $304.1 million of loss from failures of the Culmback and Tolt River dams. This averaged 55.6 percent of the total exposure for each dam failure scenario. Applying these results as a regional correlation to those dams for which detailed mapping is not available would generate loss estimates as follows:

- Cedar River Dam—$555,584,996
- Green River (Howard Hanson)—$7,943,328,466
- White River (Mud Mountain)—$8,788,279,437.

10.7.3 Critical Facilities and Infrastructure

Transportation routes are vulnerable to dam inundation and have the potential to be wiped out, creating isolation issues. This includes all roads, railroads and bridges in the path of the dam inundation. Those that are most vulnerable are those that are already in poor condition and would not be able to withstand a large water surge. Utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas.

HAZUS-MH was used to estimate the loss potential to critical facilities identified as exposed to dam failure inundation. Using depth/damage function curves to estimate the percent of damage to the building and the building contents, HAZUS-MH correlates these estimates to an estimate of functional downtime (the estimated time it will take to restore a facility to 100 percent of its functionality):

- On average, critical facilities would receive 2.3 percent damage to the structure and 42.9 percent damage to the contents during a dam failure event.
- The estimated average time to restore damaged facilities to full functionality is 534 days.

10.7.4 Environment

The environment would be vulnerable to a number of risks in the event of dam failure. Inundation can introduce foreign elements and debris into local waterways. This could result in destruction of downstream habitat and could have detrimental effects on many species of animals, especially endangered species such as salmon. The extent of vulnerability of the environment is the same as the extent of exposure.

10.8 FUTURE TRENDS IN DEVELOPMENT

Since the dam failure inundation areas overlie the mapped floodplain areas, the future trends for development in these areas is the same as described for the flood risk assessment in Section 9.8.

10.9 SCENARIO

In a worst-case scenario, a shallow earthquake with a magnitude of 7.5 could be enough to cause dam failure in many King County dams of concern. An earthquake such as this could lead to liquefaction of the ground soils where the dams are located. This could occur without warning in the middle of the night when residents in river-front homes and campers are asleep and unprepared to evacuate.

Additionally, in light of recent concerns surrounding Howard Hanson Dam, the inability of a dam to operate at 100 percent of its capacity is a major concern for dams that are used for flood control. Flood control systems downstream of these facilities are designed using assumptions of operability of these facilities. Dams that are forced to release at rates higher than the design specifications of downstream facilities jeopardize the function of those downstream facilities.

The impacts of climate change on dam operations could have significant flood impacts downstream of these facilities, without any actual failure of the dam.

10.10 ISSUES

The most significant issue associated with dam failure involves the properties and populations in the inundation zones. Flooding as a result of a failure would significantly impact these areas. Additionally, there is often limited warning time for dam failure. These events are frequently associated with other natural hazard events such as earthquakes, landslides or severe weather, which limits their predictability and compounds the hazard. Important issues associated with dam failure hazards include but are not limited to the following:

- Dam failure mapping that estimates flood depths is needed to better assess the risk associated with dam failure.
- Most dam failure mapping required at state and federal levels requires determination of the probable maximum flood. While the probable maximum flood represents a worst-case scenario, it is generally the event with the lowest probability of occurrence. Mapping of dam failure scenarios that are less extreme than the probable maximum flood, but have a higher probability of occurrence, can be valuable to emergency managers and community officials downstream of high hazard facilities.

- The concept of residual risk associated with structural flood control projects should be considered in the design of capital projects and the application of land use regulations.
- Addressing security concerns and the need to inform the public of the risk associated with dam failure is a challenge for public officials.

CHAPTER 11.
EARTHQUAKE

11.1 EARTHQUAKE DEFINED

The following definition applies in the discussion of earthquake hazards:

- **Earthquake**—An earthquake is the shaking of the ground caused by an abrupt shift of rock along a fracture in the earth or a contact zone between tectonic plates. Earthquakes are typically measured in both magnitude and intensity.

11.2 GENERAL BACKGROUND

11.2.1 How Earthquakes Happen

The Puget Sound region is seismically active, with hundreds of earthquakes occurring each year. Most are so small that only sensitive instruments can detect them. However, at least 20 damaging earthquakes have occurred in Western Washington during the past 125 years. Large quakes in 1946, 1949, 1965 and 2001 killed 16 people and caused more than $2 billion in damage. The Pacific Northwest has been studied extensively in recent years, yielding valuable new insights. It is now generally agreed that three source zones exist for Puget Sound quakes: a shallow (crustal) zone; the Cascadia Subduction Zone; and a deep, intraplate "Benioff" zone. These are shown in Figure 11-1. More than 90 percent of Pacific Northwest earthquakes occur along the boundary between the Juan de Fuca plate and the North American plate.

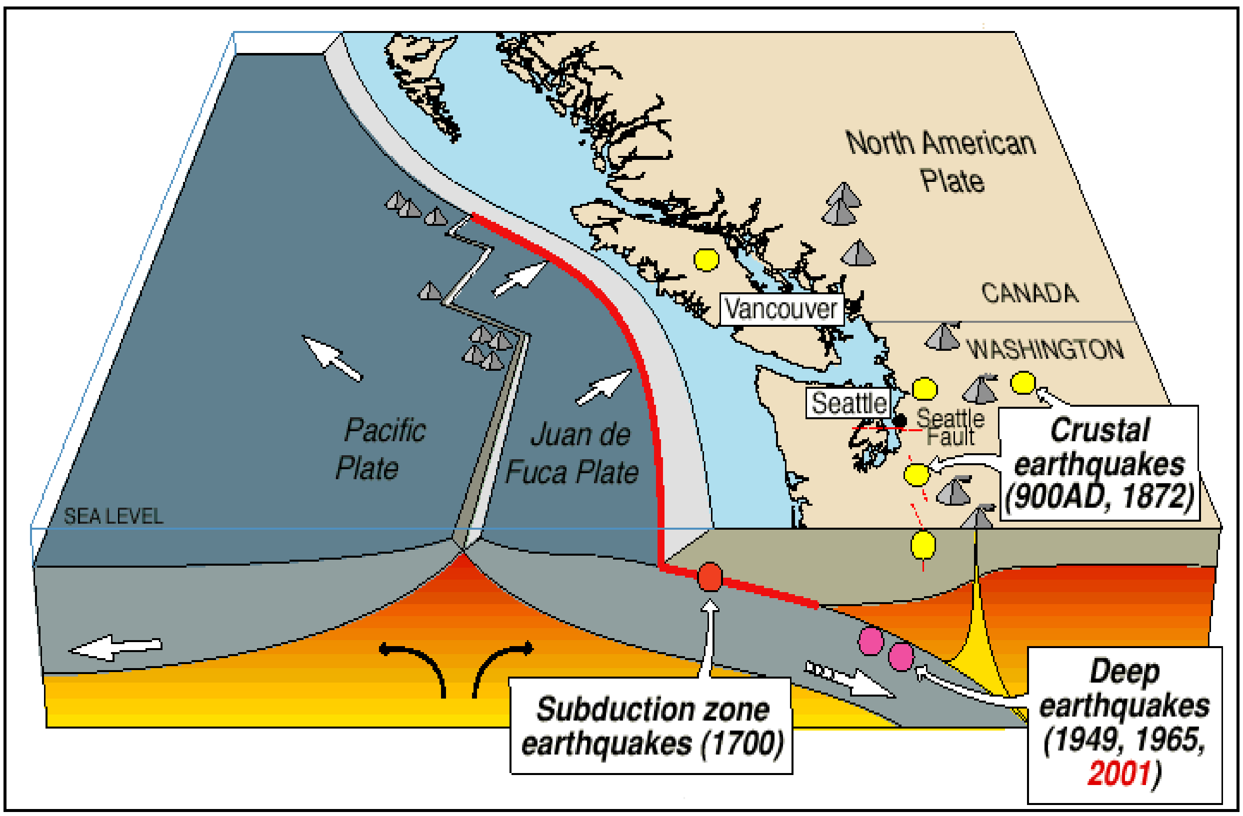


Figure 11-1. Earthquake Types in Western Washington

Geologists classify faults by their relative hazards. Active faults, which represent the highest hazard, are those that have ruptured to the ground surface during the Holocene period (about the last 11,000 years). Potentially active faults are those that displaced layers of rock from the Quaternary period (the last 1,800,000 years). Determining if a fault is "active" or "potentially active" depends on geologic evidence, which may not be available for every fault. Although there are probably still some unrecognized active faults, nearly all the movement between the two plates, and therefore the majority of the seismic hazards, are on the well-known active faults.

Faults are more likely to have earthquakes on them if they have more rapid rates of movement, have had recent earthquakes along them, experience greater total displacements, and are aligned so that movement can relieve accumulating tectonic stresses. A direct relationship exists between a fault's length and location and its ability to generate damaging ground motion at a given site. In some areas, smaller, local faults produce lower magnitude quakes, but ground shaking can be strong, and damage can be significant as a result of the fault's proximity to the area. In contrast, large regional faults can generate great magnitudes but, because of their distance and depth, may result in only moderate shaking in the area.

11.2.2 Classifying and Measuring Earthquakes

Earthquakes are classified according to the amount of energy released as measured by magnitude or intensity scales. While several scales have been defined, currently the most commonly used are the moment magnitude, or Mw, and the modified Mercalli intensity. Estimates of moment magnitude roughly agree with estimates using other scales, such as the local magnitude scale commonly called the Richter scale. One advantage of the moment magnitude scale is that, unlike other magnitude scales, it does not saturate at the upper end. That is, there is no value beyond which all large earthquakes have about the same magnitude. For this reason, moment magnitude is now the most often used estimate of large earthquake magnitudes. Table 11-1 presents a classification of earthquakes according to their magnitude. Table 11-2 compares the moment magnitude scale to the modified Mercalli intensity scale.

Another element of earthquake hazard assessment is the calculation of expected ground motion. This involves determining the annual probability that certain ground motion accelerations will be exceeded, then summing the annual probabilities over the time period of interest. The most commonly mapped ground motion parameters are the horizontal and vertical peak ground accelerations, or PGA, for a given soil or rock type. Maps of PGA values form the basis of seismic zone maps that are included in building codes, including the International Building Code and its predecessor the Uniform Building Code.

Building codes that include seismic provisions specify the horizontal force due to lateral acceleration that a building should be able to withstand during an earthquake. PGA values are directly related to these lateral forces that could damage short-period structures (single-family dwellings). Longer period response components determine the lateral forces that damage larger structures with longer natural periods (apartment buildings, factories, high-rises, bridges). Table 11-3 summarizes damage potential by PGA factors compared to the Mercalli scale.

The impact of an earthquake on structures and infrastructure is largely a function of ground shaking, liquefaction and distance from the source of the quake. Liquefaction generally occurs in soft, unconsolidated sedimentary soils. A program called the National Earthquake Hazard Reduction Program, or NEHRP, creates maps based on soil characteristics so that locations potentially subject to liquefaction may be identified. Table 11-4 summarizes NEHRP soil classifications.

TABLE 11-1.
EARTHQUAKE MAGNITUDE CLASSES

Magnitude Class	Magnitude Range (M = magnitude)
Great	M > 8
Major	7 <= M < 7.9
Strong	6 <= M < 6.9
Moderate	5 <= M < 5.9
Light	4 <= M < 4.9
Minor	3 <= M < 3.9
Micro	M < 3

TABLE 11-2.
EARTHQUAKE MAGNITUDE AND INTENSITY

Magnitude (Mw)	Intensity (Modified Mercalli)	Description
1.0 – 3.0	I	I. Not felt except by a very few under especially favorable conditions
3.0 – 3.9	II – III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 – 4.9	IV – V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
5.0 – 5.9	VI – VII	VI. Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
6.0 – 6.9	VII – IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	VIII and higher	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

**TABLE 11-3.
MERCALLI SCALE AND PEAK GROUND ACCELERATION COMPARISON**

Mercalli Scale	Potential Damage	Estimated PGA
I	None	0.017
II-III	None	0.017
IV	None	0.014-0.039
V	Very Light	0.039-0.092
VI	None to Slight; USGS-Light	0.02-0.05
	Unreinforced Masonry-Stair Step Cracks; Damage to Chimneys; Threshold of Damage	0.04-0.08 0.06-0.07 0.06-0.13 0.092-0.18
VII	Slight-Moderate; USGS-Moderate	0.05-0.10
	Unreinforced Masonry-Significant; Cracking of parapets	0.08-0.16 0.10-0.15
	Masonry may fail; Threshold of Structural Damage	0.1 0.18-0.34
VIII	Moderate-Extensive; USGS: Moderate-Heavy	0.10-0.20
	Unreinforced Masonry-Extensive Cracking; fall of parapets and gable ends	0.16-0.32 0.25-0.30 0.13-0.25 0.2 0.35-0.65
IX	Extensive-Complete; USGS-Heavy	0.20-0.50
	Structural collapse of some un-reinforced masonry buildings; walls out of plane. Damage to seismically designed structures	0.32-0.55 0.50-0.55 0.26-0.44 0.3 0.65-1.24
X	Complete ground failures; USGS- Very Heavy (X+); Structural collapse of most un-reinforced masonry buildings; notable damage to seismically designed structures; ground failure	0.50-1.00

**TABLE 11-4.
NEHRP SOIL CLASSIFICATION SYSTEM**

NEHRP Soil Type	Description	Mean Shear Velocity to 30 m (m/s)
A	Hard Rock	1,500
B	Firm to Hard Rock	760-1,500
C	Dense Soil/Soft Rock	360-760
D	Stiff Soil	180-360
E	Soft Clays	< 180
F	Special Study Soils (liquefiable soils, sensitive clays, organic soils, soft clays >36 m thick)	

11.3 HAZARD PROFILE

Hundreds of earthquakes occur in the Puget Sound region each year. While the majority of these events register a magnitude of 3 or lower on the Richter scale, earthquakes measuring up to 7.1 have been recorded. Recent studies suggest that earthquakes of a Magnitude 8 or greater have occurred in the region and that similar seismic events are possible in the future. Several major faults are located in the vicinity. Small shallow earthquakes (up to Magnitude 4) associated with these faults are likely. Shallow earthquakes of greater magnitude are expected to occur infrequently in this area.

Earthquakes can last from a few seconds to over five minutes; they may also occur as a series of tremors over a period of several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties may result from falling objects and debris, because the shocks shake, damage, or demolish buildings and other structures. Disruption of communications, electrical power supplies and gas, sewer and water lines should be expected. Earthquakes may trigger fires, dam failures, landslides or releases of hazardous material, compounding their disastrous effects.

11.3.1 Past Events

Historically, King County earthquake activity has been slightly above the Washington State average. It is 268 percent greater than the overall U.S. average. Table 11-5 lists past seismic events in King County.

TABLE 11-5.
HISTORICAL EARTHQUAKES IMPACTING KING COUNTY

Date	Magnitude	Epicenter Location
January 2009	4.5	Bremerton
July 2002	3.1	North Bend
May 2002	4.2	Friday Harbor, San Juan Islands
March 2001	3.4	Tacoma
February 28, 2001	6.8	Olympia (Nisqually)
July 3, 1999	5.8	5 miles north of Satsop
March 1998	3.1	Pierce County
February 1998	2.8	Northeast of Seattle
July 1997	3.1	Duvall
June 1997	2.7	Puget Sound
April 1997	4.9	Puget Sound off Vashon Island
February 1997	3.0	Southeast of Seattle
November 1996	2.9	Puget Sound
July 1996	5.4	5 miles east-northeast of Duvall
May 3, 1996	5.5	Duvall
February 14, 1981	5.5	Mt. St. Helens
April 29, 1965	6.6	11 miles north of Tacoma
January 13, 1949	7.0	8 miles east-northeast of Olympia
April 1945	5.7	8 miles south-southeast of North Bend

11.3.2 Location

Where Earthquakes Occur

Cascadia Subduction Zone

In Western Washington, the primary plates of interest are the Juan De Fuca and North American plates. The Juan De Fuca plate moves northeast with respect to the North American plate at a rate of about an inch and a half per year. The boundary where these plates converge, the Cascadia Subduction Zone, lies approximately 50 miles offshore of the west coastline and extends from the middle of Vancouver Island in British Columbia to northern California. As it collides with the North American plate, the Juan De Fuca plate slides beneath the continent and sinks into the earth's mantle. The sliding of one plate below another is called "subduction." Subduction zone earthquakes occur as a direct result of the convergence of these two plates. Earthquakes at subduction zone boundaries are the world's greatest earthquakes. A subduction earthquake off the coast of Washington or Oregon where the plates converge would typically have a minute or more of strong ground shaking at Magnitude 8 to 9.5 on the Richter scale. Usually, damaging tsunamis and numerous large aftershocks immediately follow these types of earthquakes.

There are no reports of such earthquakes in the Cascadia Subduction Zone off the Oregon or Washington coast since the first written records of permanent occupation by Europeans in 1833. However, scientific evidence suggests that there may have been as many as five of these energy releases in the past 2,000 years, with an irregular recurrence interval of 150 to 1,100 years. Written tsunami records from Japan, correlated with studies of partially submerged forests in coastal Washington and Oregon, give a probable date for the most recent of these huge quakes as January 26, 1700.

Since the installation in 1969 of a multi-station seismograph network in Washington, there has been no evidence of even small subduction-type earthquakes in the Cascadia region, indicating that the plates are locked. However, parts of subduction zones in Japan and Chile also appear to have had very low levels of seismicity prior to experiencing great earthquakes. Therefore, the historical seismic inactivity observed along the coastal region of Washington and Oregon does not negate the possibility of an earthquake there with a magnitude greater than 8. Recent measurements near Seattle indicate that significant strain is accumulating parallel to the direction of convergence between the Juan de Fuca and North America plates, as would be expected prior to a great thrust earthquake off the coast of Oregon, Washington and British Columbia.

Benioff Deep Zone

Western Washington can experience deep earthquakes of Magnitude 6 to 7.4 on the Richter scale. This occurs within the Juan de Fuca plate at depths of about 30 to 40 miles. As the Juan de Fuca plate moves beneath North America, it becomes denser than the surrounding mantle rocks and breaks apart, causing Benioff zone earthquakes. The largest Benioff zone earthquakes occur where the Juan de Fuca plate begins to bend even more steeply downward, forming a knee.

The largest of these events recorded in modern times were the 7.1-magnitude Olympia earthquake in 1949 and the 6.8 magnitude Nisqually earthquake in 2001. Strong shaking during the Olympia earthquake lasted about 20 seconds. During the Nisqually quake, shaking lasted from about 30 seconds to more than 2 minutes. Since 1870, there have been seven deep earthquakes in the Puget Sound basin with measured or estimated magnitudes of 6.0 or larger. The epicenters of all of these events have been within about 50 miles of each other between Olympia and just north of Tacoma. Scientists estimate the recurrence interval for this type of quake to be 30 to 40 years for magnitude 6.5, and 50 to 70 years for magnitude 7.0. Because of their depth, intraplate earthquakes are least likely to produce significant aftershocks.

Crustal Zone

The third source zone is the crust of the North American plate. These are known as shallow earthquakes. Shallow earthquakes with magnitude of 7 or more on the Richter scale can happen anywhere in the Puget Sound region. Such earthquakes have the potential to cause greater loss of life and property than any other kind of disaster. Fortunately, great crustal quakes do not seem to happen very often—perhaps no more than once every 1,000 years.

The structure of the crust in the Puget Sound area is complex, with large sedimentary rock-filled basins beneath Tacoma, Seattle and Everett. The Seattle basin is the deepest, at about 5 to 6 miles. In addition to the 1872 Mount Baker earthquake, seismologists have found evidence that a devastating crustal quake occurred on a fault near Seattle approximately 1,100 years ago. The Duvall Fault near Lake Margaret on the King-Snohomish County border has produced two Magnitude 5.3 earthquakes in the past 70 years (1932 and 1996).

How many other crustal faults pose significant earthquake hazards to the Puget Sound region is not yet known, but geologists and geophysicists are studying the South Whidbey Island fault and the Olympia fault for evidence of young earthquakes. In addition, a potential Everett fault has been identified and is currently being researched.

Crustal earthquakes are the least predictable of Puget Sound’s seismic threats and are the most likely to be followed by significant aftershocks. Following a great crustal earthquake of Magnitude 7.0 or more, one of the greatest dangers to human life is that buildings or other structures damaged in the initial shock but still in use and believed safe could collapse in a strong aftershock.

Maps of Earthquake Impact in King County

The impact of an earthquake is largely a function of the following components:

- Ground shaking (ground motion accelerations)
- Liquefaction (soil instability)
- Distance from the source (both horizontally and vertically)

King County has identified seismic hazard areas in its Sensitive Areas Map Folio (December 1990). Primary seismic hazard areas include areas of post-glacial, modern floodplain river sedimentation. Secondary seismic hazard areas include recessional glacial outwash deposits.

Shake Maps

A shake map is a representation of ground shaking produced by an earthquake. The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because shake maps focus on the ground shaking produced by the earthquake, rather than the parameters describing the earthquake source. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth’s crust. A shake map is designed as a rapid response tool to portray the extent and variation of ground shaking throughout an affected region immediately following significant earthquakes.

Ground motion and intensity maps are derived from peak ground motion amplitudes recorded on seismic sensors (accelerometers), with interpolation based on estimated amplitudes where data are lacking, and site amplification corrections. These readings are recorded by state and federal agencies. Color-coded instrumental intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity.

A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain ground motion, such as the 10-percent probability of exceedance in 50 years. This level of ground shaking has been used for designing buildings in high seismic areas. Map 11-1 illustrates the estimated ground motion for a 100-year probabilistic earthquake in King County.

Earth quake scenarios describe the expected ground motions and effects of specific hypothetical large earthquakes for a region. Maps of these scenarios can be used to support all phases of emergency management. For the King County planning area, shake maps are available for two scenarios:

- Seattle Fault Scenario—The Seattle Fault scenario is for a Magnitude 7.2 event with a depth of about 6 miles and an epicenter 10 miles west of Seattle. This scenario is illustrated in Map 11-2.
- South Whidbey Fault Scenario—The South Whidbey Fault scenario is for a Magnitude 7.4 event with a depth of 0 miles and an epicenter 2 miles northeast of Langley. This scenario is illustrated in Map 11-3.

NEHRP Soil Maps

NEHRP soil types define the locations that will be significantly impacted by an earthquake. NEHRP Soils B and C typically can sustain low-magnitude ground shaking without much effect. The areas that are commonly most affected by ground shaking have NEHRP Soils D, E and F. Map 11-4 shows NEHRP soil classifications in the county.

Liquefaction Maps

In general areas with NEHRP Soils D, E and F are also susceptible to liquefaction, a secondary effect of an earthquake in which soils lose their shear strength and flow or behave as liquid, thereby damaging structures that derive their support from the soil. If there is a dry soil crust, excess water will sometimes come to the surface through cracks in the confining layer, bringing liquefied sand with it, creating sand boils, colloquially called “sand volcanoes.” Soil liquefaction maps are useful tools to assess potential damage from earthquakes. Map 11-5 shows the liquefaction susceptibility in King County.

11.3.3 Frequency

The USGS has created a map of peak ground acceleration that takes into account current information on several fault zones. The Puget Sound area is in a higher-risk area, with a 2 percent probability in a 50-year period of ground shaking from a subduction zone event exceeding 70 percent of gravity. Figure 11-2 shows the expected peak horizontal ground motions for this probability (USGS Web Site, 2007).

The USGS estimated that a Cascadia Subduction Zone earthquake has a 10 to 15 percent probability of occurrence in 50 years, and a crustal zone earthquake has a recurrence interval of about 500 to 600 years. In general, it is difficult to estimate the probability of occurrence of crustal earthquake events. Earthquakes on the South Whidbey and Seattle faults have a 2 percent probability of occurrence in 50 years. A Benioff zone earthquake has an 85 percent probability of occurrence in 50 years, making it the most likely of the three types.

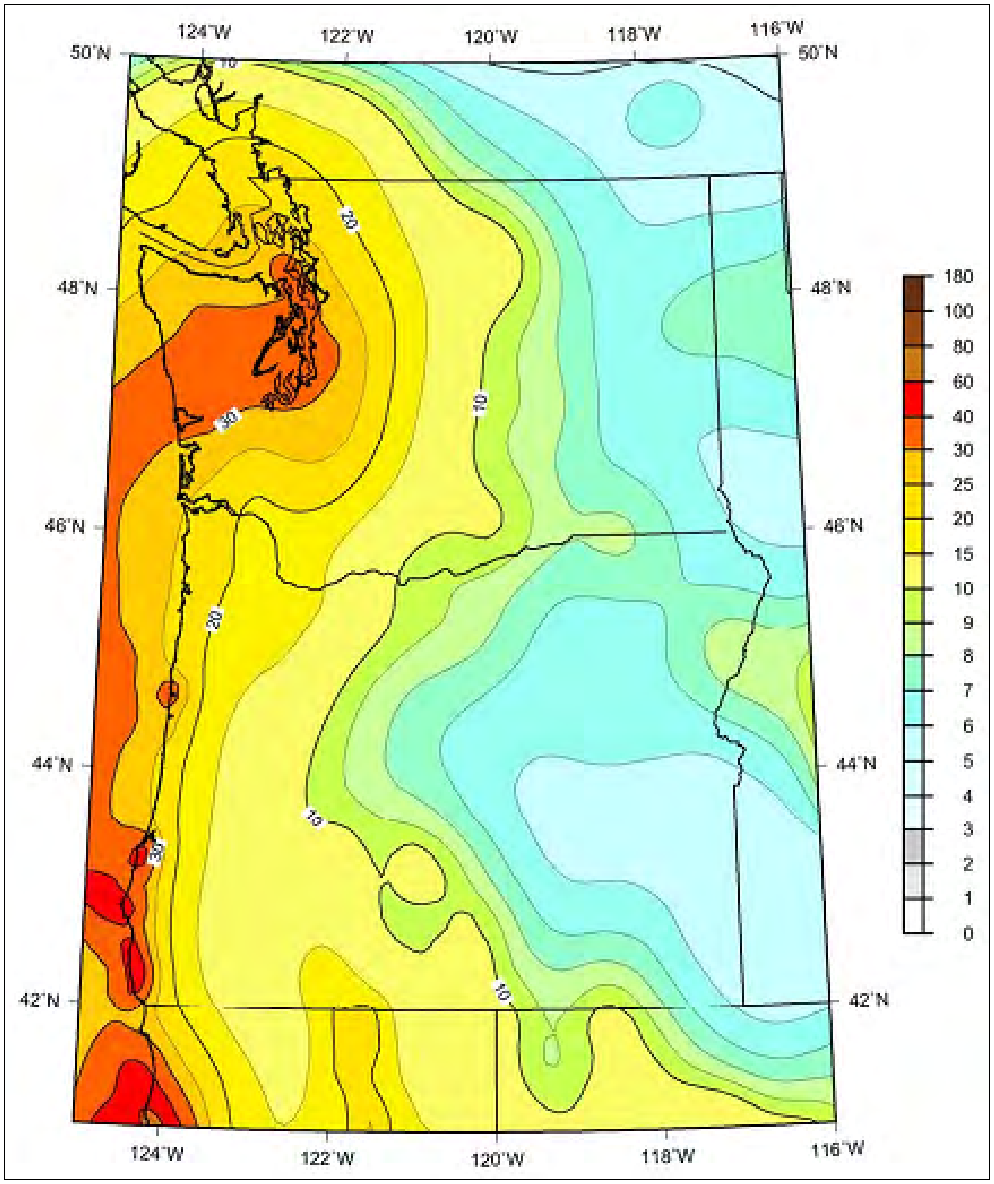


Figure 11-2. Peak Acceleration (%g) with 10-Percent Probability of Exceedance in 50 Years

11.3.4 Severity

The severity of an earthquake can be expressed in terms of intensity or magnitude. Intensity represents the observed effects of ground shaking on people, buildings, and natural features. Magnitude is related to the amount of seismic energy released at the hypocenter of the earthquake. It is based on the amplitude of the earthquake waves recorded on instruments. Magnitude is thus represented by a single, instrumentally determined value. Intensity varies depending on the location with respect to the earthquake epicenter. The expected magnitude of earthquakes in King County by type is as follows:

- Cascadia Subduction Zone—Expected Magnitude up to 9.0 for approximately 4 minutes with aftershocks
- Benioff—Expected Magnitude up to 7.1 with no aftershocks
- Crustal—Expected Magnitude up to 7.1 with some aftershocks

11.3.5 Warning Time

There is no current reliable way to predict the day or month that an earthquake will occur at any given location. Current research is being done with warning systems that use the low energy waves that precede major earthquakes. These potential warning systems give approximately 40 seconds notice that a major earthquake is about to occur. The warning time is very short but it could allow for someone to get under a desk, step away from a hazardous material they are working with or shut down a computer system.

11.4 SECONDARY HAZARDS

Earthquakes can cause large and sometimes disastrous landslides and mudslides. River valleys are vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction occurs when water-saturated sands, silts or gravelly soils are shaken so violently that the individual grains lose contact with one another and float freely in the water, turning the ground into a pudding-like liquid. Building and road foundations lose load-bearing strength and may sink quicksand-like into what was previously solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risk exposure to earthquakes.

11.5 CLIMATE CHANGE IMPACTS

The impacts of global climate change on earthquake probability are unknown. Some scientists say melting glaciers could induce tectonic activity. As ice melts and waters runs off, tremendous amounts of weight are shifted on the Earth’s crust. As newly freed crust settles back to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA, 2004).

The secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could fail prematurely during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. Wildland fire risks associated with earthquakes could be significantly enhanced by drought conditions triggered by climate change. There are currently no models available to estimate these impacts.

11.6 EXPOSURE

11.6.1 Population

The entire population of the King County is potentially exposed to earthquakes.

11.6.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for exposure of general property to the earthquake hazard.

11.6.3 Critical Facilities and Infrastructure

The district has maintenance responsibility for over 500 facilities that are critical to district operations, including levees, revetments, pump stations and the district’s Flood Warning Center. All critical district facilities and infrastructure are exposed to potential impacts from earthquakes. Levees and revetments can be highly susceptible to significant damage from earthquake, especially in areas with soft unstable soils. The exposure analysis for earthquake identified facilities that lie within NEHRP Type D and Type E soils.

The model distinguishes between levees and revetments; all other district facilities, such as the building that houses district offices and the flood warning center, are classified as "Other." Table 11-6 lists critical facility exposure by river basin. In all, it is estimated that over 114 miles of levees and revetments have earthquake susceptibility due to their construction on soft, unstable soils. The estimated replacement cost for these facilities exceeds $1.2 billion.

TABLE 11-6.
CRITICAL DISTRICT FACILITIES ON NEHRP TYPE D AND TYPE E SOILS

River Basin	Facility Type	Soil Type	Length of Facility Exposed (feet)	Replacement cost[a]
South Fork Skykomish	Levee	E—Soft Soil	2,951	$5,901,061
	Revetment	E—Soft Soil	1,462	$2,924,997
Upper Snoqualmie	Revetment	D—Stiff Soil	4,928	$9,856,331
	Other	E—Soft Soil	372	$743,042
	Levee	E—Soft Soil	44,631	$89,261,581
	Revetment	E—Soft Soil	29,868	$59,735,426
Lower Snoqualmie	Revetment	D—Stiff Soil	3,254	$6,507,397
	Levee	E—Soft Soil	45,754	$91,508,309
	Other	E—Soft Soil	133	$266,532
	Revetment	E—Soft Soil	110,398	$220,795,631
Sammamish	Revetment	D—Stiff Soil	10,419	$20,836,391
	Revetment	E—Soft Soil	71,587	$143,074,058
Cedar	Levee	D—Stiff Soil	1,119	$2,238,838
	Revetment	D—Stiff Soil	3,438	$6,875,890
	Levee	E—Soft Soil	17,341	$34,681,727
	Revetment	E—Soft Soil	28,000	$55,999,213
Green	Levee	D—Stiff Soil	634	$1,267,730
	Revetment	D—Stiff Soil	2,002	$4,004,121
	Levee	E—Soft Soil	10,7563	$215,125,281
	Revetment	E—Soft Soil	78,638	$157,276,732
White	Levee	D—Stiff Soil	711	$1,421,384
	Revetment	D—Stiff Soil	1,801	$3,601,805
	Levee	E—Soft Soil	8,764	$17,527,421
	Revetment	E—Soft Soil	27,137	$54,274,515
Total			**602,905**	**$1,205,805,959**

a. Replacement cost determined using $2,000 per foot, based on county data from past projects

11.6.4 Environment

Environmental problems as a result of an earthquake can be numerous. Secondary hazards will likely have some of the most damaging effects on the environment. Earthquake-induced landslides in landslide-prone areas can significantly impact surrounding habitat. It is also possible for streams to be rerouted after an earthquake. This can change the water quality, possibly damaging habitat and feeding areas. There is a possibility of streams fed by groundwater wells drying up because of changes in underlying geology.

11.7 VULNERABILITY

11.7.1 Population

The vulnerable populations for the earthquake hazard are those living in economically disadvantaged households, those over 65 and those under 16. The population of these groups for all of King County constitutes he vulnerable population for earthquakes.

11.7.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for vulnerability of general property to the earthquake hazard.

11.7.3 Critical Facilities and Infrastructure

HAZUS-MH estimates the expected time required to restore critical facilities to fully functional use. The model presents this data in the form of percent probability of being functional at specified time increments: 1, 3, 7, 14, 30 and 90 days after the event. For example, HAZUS-MH may estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. The functionality analysis was performed for three district critical facilities:

- Pump Plant P-1, on Monster Road along the lower Green River in Renton
- Pump Plant P-17 on Minkler Boulevard along the lower Green River in Tukwila
- The King County Building on Jackson Street in Seattle where the district maintains its offices.

The analysis was run for the 100-year and 500-year earthquake events and the Seattle Fault and South Whidbey Fault scenario events. Results are summarized in Table 11-7.

11.7.4 Environment

The environment vulnerable to earthquake hazard is the same as the environment exposed to the hazard.

11.8 FUTURE TRENDS IN DEVELOPMENT

King County's population increased by approximately 9 percent between 2000 and 2009, and has averaged 1.19 percent annual growth since 1990. It is anticipated that King County will continue to grow at similar rates in the near future. As a special purpose district with a principle mission to manage flood risk, King County Flood Control District has a limited role in mitigating increased earthquake risk associated with future development. The district's focus for earthquake risk mitigation will be to manage the specific facilities for which it has responsibility. As facilities are upgraded or replaced, the district will have the opportunity to incorporate earthquake risk reduction into the design of the improvements.

District funds are based on a countywide levy tax. As the population increases and additional homes are built to house the increased population, the district's revenue increases to reflect new construction and a maximum annual increase of 1 percent, under the provisions of Initiative 747. While this could increase total revenues over time, it is unlikely to keep pace with inflation over the long term.

TABLE 11-7.
IMPACTS ON DISTRICT FACILITIES

	Probability of Being Fully Functional (%)						Economic Loss
	Day 1	Day 3	Day 7	Day 14	Day 30	Day 90	
100-Year Probabilistic							
Pump Plant P-1	52.0	72.3	75.9	76.4	78.1	86.6	$10,970,100
Pump Plant P-17	56.3	78.4	82.2	82.7	84.1	90.7	$8,448,160
King County Building	50.1	68.9	74.2	77.5	81.7	88.4	—
500-Year Probabilistic							
Pump Plant P-1	33.4	61.2	68.0	69.2	72.6	85.9	$14,021,800
Pump Plant P-17	35.2	64.8	72.0	73.2	76.6	88.7	$12,453,800
King County Building	32.2	59.6	65.3	68.0	70.4	82.4	—
Seattle Fault Scenario							
Pump Plant P-1	27.5	61.9	70.6	71.7	74.6	86.4	$13,830,900
Pump Plant P-17	41.1	73.9	80.2	80.7	82.1	89.2	$10,219,600
King County Building	39.6	67.2	72.0	75.1	79.8	86.4	—
South Whidbey Fault Scenario							
Pump Plant P-1	78.3	86.0	86.4	86.7	87.5	92.1	$5,836,440
Pump Plant P-17	85.9	94.4	94.8	94.9	95.2	97.0	$2,516,850
King County Building	71.5	82.3	84.0	85.4	88.2	90.5	—

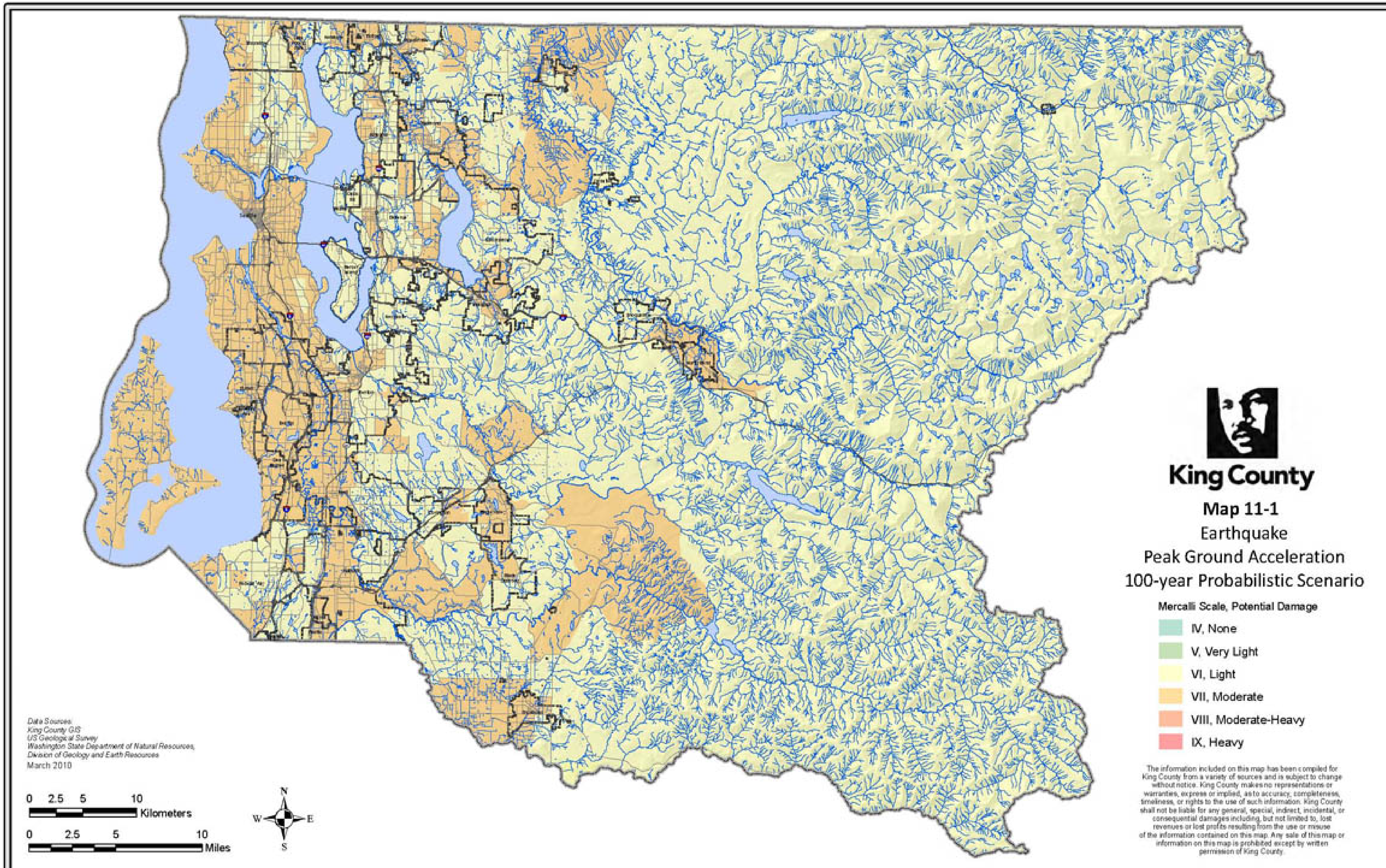
11.9 SCENARIO

A subduction zone earthquake affecting King County could have a magnitude as high as 8.5. Potential warning systems could give approximately 40 seconds notice that a major earthquake is about to occur. This would not provide adequate time for preparation. An earthquake of this magnitude would lead to massive structural failure of property on NEHRP C-D, D and D-E soils. Levees and revetments built on these poor soils would likely fail, representing a loss of critical district infrastructure. This event would cause secondary hazards including landslides and mudslides that would further damage structures. River valley hydraulic-fill sediment areas are also vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction would occur in water-saturated sands, silts or gravelly soils.

11.10 ISSUES

Important issues for the district associated with an earthquake include but are not limited to the following:

- The district has over 114 miles of earthen levees and revetments on soft, unstable soil. These soils are prone to liquefaction, which would severely undermine the integrity of these facilities.
- A worst-case scenario would be the occurrence of a large seismic event during a flood or high-water event. Levee failures would happen at multiple locations, doubling the impacts of the individual events.
- Earthquakes could trigger other natural hazard events such as dam failures, landslides or volcanic activity, which could severely impact district facilities.
- Establishing appropriate geotechnical standards that take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.


King County
Map 11-1
Earthquake
Peak Ground Acceleration
100-year Probabilistic Scenario
Mercalli Scale, Potential Damage
IV, None
V, Very Light
VI, Light
VII, Moderate
VIII, Moderate-Heavy
IX, Heavy
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Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
March 2010
0 2.5 5 10
Kilometers
0 2.5 5 10
Miles
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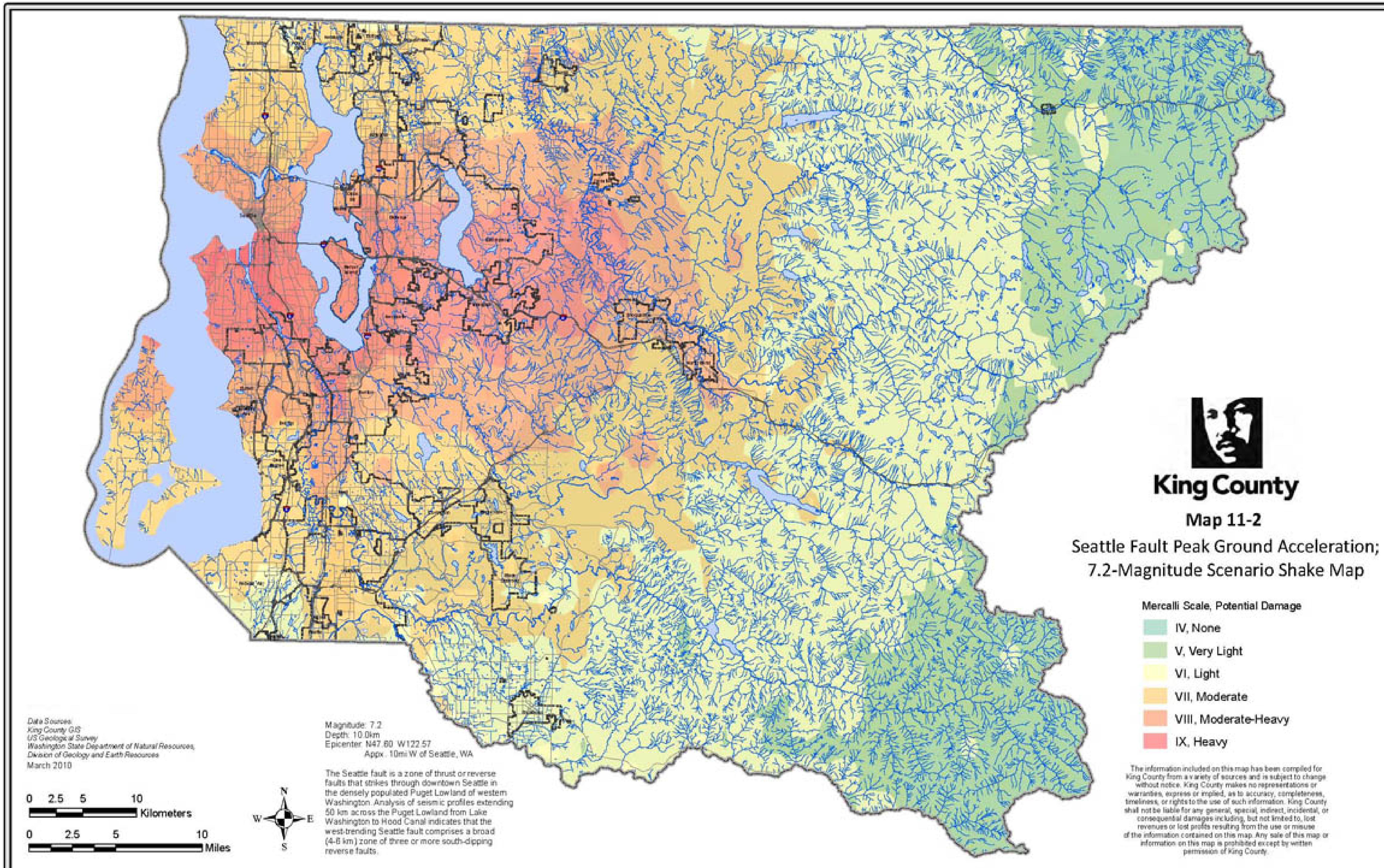
King County
Map 11-2
Seattle Fault Peak Ground Acceleration;
7.2-Magnitude Scenario Shake Map
Mercalli Scale, Potential Damage
IV, None
V, Very Light
VI, Light
VII, Moderate
VIII, Moderate-Heavy
IX, Heavy
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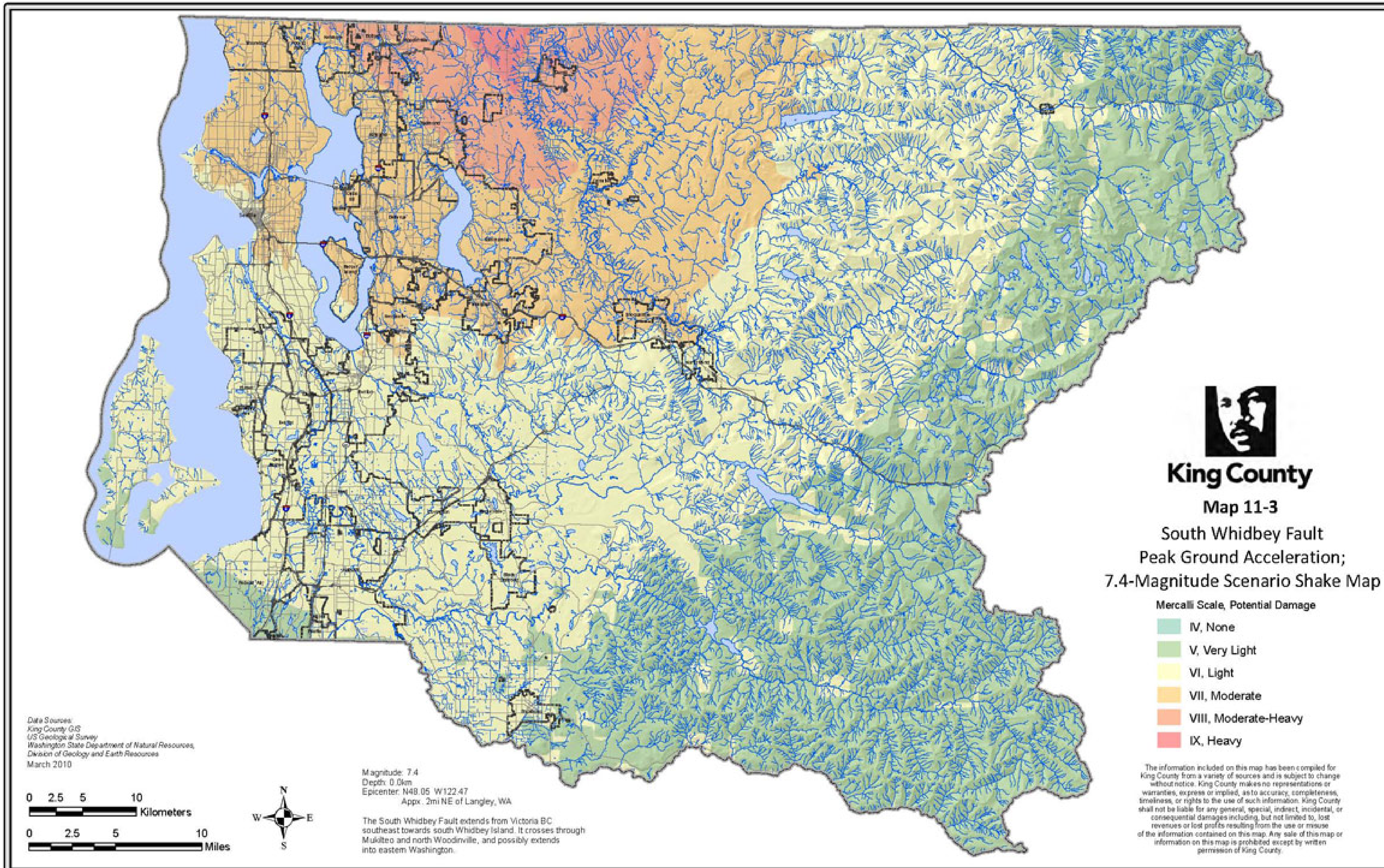
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources, Division of Geology and Earth Resources
March 2010
0 2.5 5 10 Kilometers
0 2.5 5 10 Miles
N
W
E
S
Magnitude: 7.2
Depth: 10.0km
Epicenter: N47.60 W122.57
Appx. 10mi W of Seattle, WA
The Seattle fault is a zone of thrust or reverse faults that strikes through downtown Seattle in the densely populated Puget Lowland of western Washington. Analysis of seismic profiles extending 50 km across the Puget Lowland from Lake Washington to Hood Canal indicates that the west-trending Seattle fault comprises a broad (4-6 km) zone of three or more south-dipping reverse faults.


King County
Map 11-3
South Whidbey Fault
Peak Ground Acceleration;
7.4-Magnitude Scenario Shake Map
Mercalli Scale, Potential Damage
IV, None
V, Very Light
VI, Light
VII, Moderate
VIII, Moderate-Heavy
IX, Heavy
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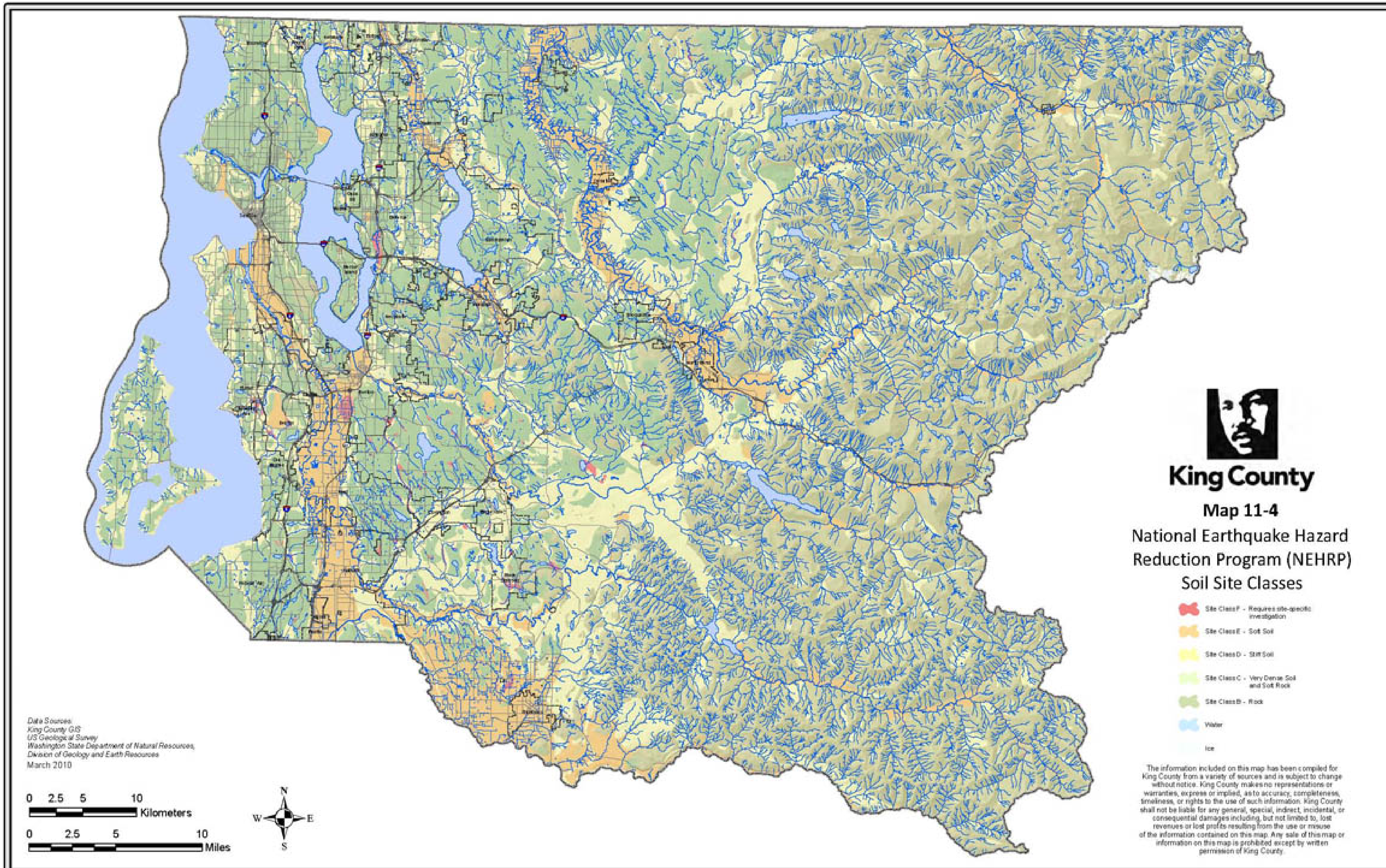
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources, Division of Geology and Earth Resources
March 2010
0 2.5 5 10 Kilometers
0 2.5 5 10 Miles
N
W
E
S
Magnitude: 7.4
Depth: 0.0km
Epicenter: N48.05 W122.47
Appx. 2mi NE of Langley, WA
The South Whidbey Fault extends from Victoria BC southeast towards south Whidbey Island. It crosses through Mukilteo and north Woodinville, and possibly extends into eastern Washington.



King County
Map 11-4
National Earthquake Hazard Reduction Program (NEHRP) Soil Site Classes
Site Class F - Requires site-specific investigation
Site Class E - Soft Soil
Site Class D - Stiff Soil
Site Class C - Very Dense Soil and Soft Rock
Site Class B - Rock
Water
Ice
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Data Sources:
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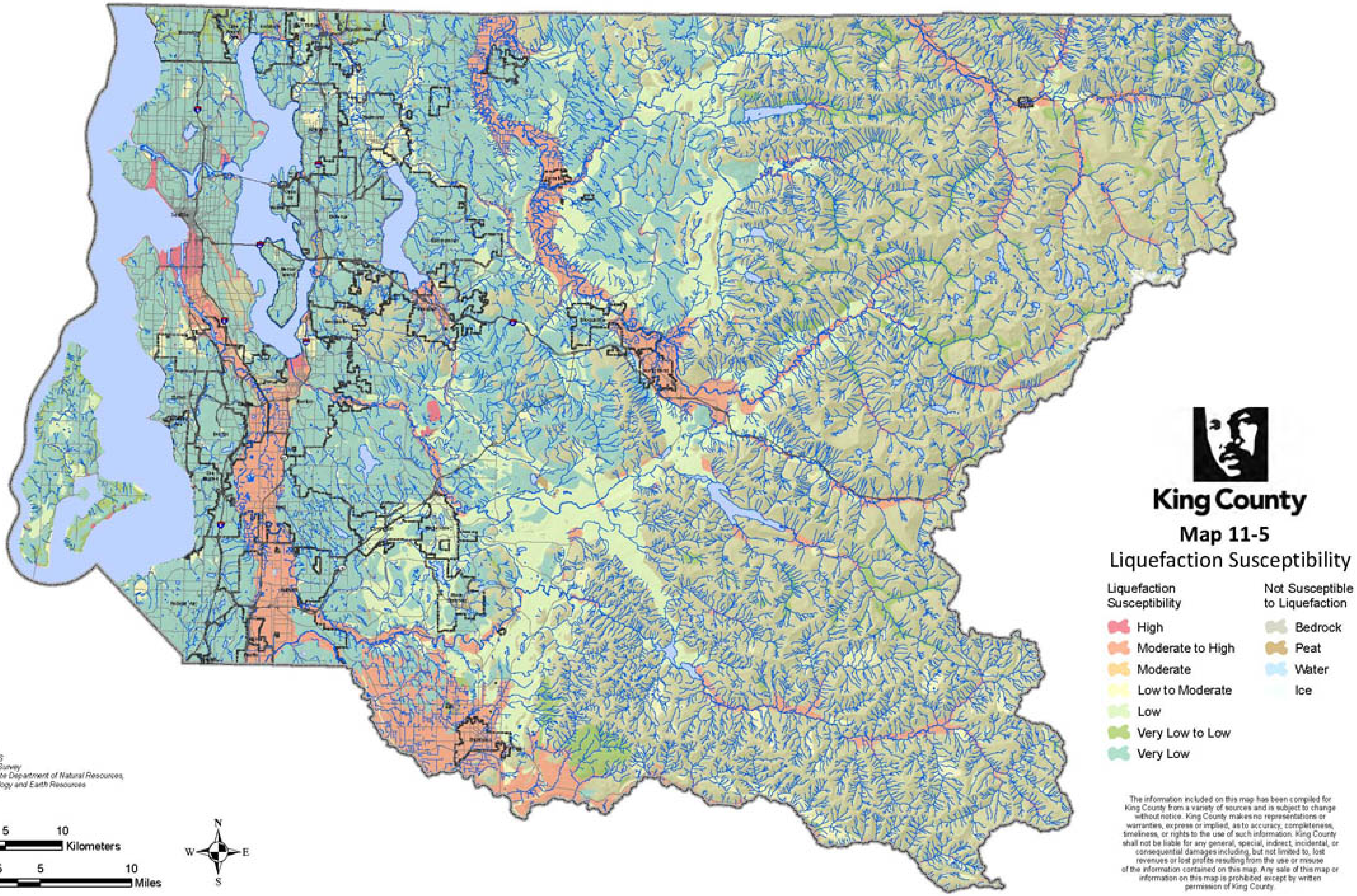
King County
Map 11-5
Liquefaction Susceptibility
Liquefaction Susceptibility
High
Moderate to High
Moderate
Low to Moderate
Low
Very Low to Low
Very Low
Not Susceptible to Liquefaction
Bedrock
Peat
Water
Ice
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
March 2010
0 2.5 5 10 Kilometers
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CHAPTER 12.
LANDSLIDES AND OTHER MASS MOVEMENTS

12.1 LANDSLIDE AND MASS MOVEMENT DEFINED

The following definitions apply in the discussion of landslide and mass movement hazards:

- **Landslide**—A landslide is the sliding movement of masses of loosened rock and soil down a hillside or slope. Slope failures occur when the strength of the soils forming the slope is exceeded by the pressure, such as weight or saturation, acting upon them. Landslides may be minor or very large, and can move at slow to very high speeds. They can be initiated by storms, earthquakes, fires, floods, volcanic eruptions, or human modification of the land.
- **Mass movements**—A collective term for landslides, debris flows, falls and sinkholes.
- **Mudslide (or Mudflow or Debris Flow)—**A river of rock, earth, organic matter and other materials saturated with water. Mudslides develop in soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt. Water pressure in the pore spaces of the material increases to the point that the internal strength of the soil is drastically weakened. The soil's reduced resistance can then easily be overcome by gravity, changing the earth into a flowing river of mud, or slurry. A debris flow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars, and anything else in its path. Although these slides behave as fluids, their hydraulic force is many times greater than that of water due to the mass of material included in them. They are among the most destructive events in nature.
- **Sinkhole**—A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

12.2 GENERAL BACKGROUND

Landsliding is caused by a combination of geological and climate conditions. The cool, rainy Pacific Northwest climate ensures that soil moisture levels remain high throughout most of the year, and in fact are often at or near saturation during the wetter winter months. The region's topography reflects glacial carving, as well as the differential erosion of weaker sediments in the 13,000 years since the last glacier disappeared. One of the most active erosive processes during this period has been the action of landslides and mudslides. This vulnerable natural setting is being steadily invaded by residential, agricultural, commercial and industrial development and the infrastructure that supports it.

Landslides are caused by one or a combination of the following factors: change in slope gradient, increased load on the land, shocks and vibrations, change in water content, groundwater movement, frost action, weathering of rocks, and removing or changing the type of vegetation covering slopes. In general, landslide hazard areas occur where the land has characteristics that contribute to the risk of the downhill movement of material.

Flows and slides are commonly categorized by the form of initial ground failure, but they may travel in a variety of forms along their paths. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material and water content.

12.3 HAZARD PROFILE

A recent study of historic landslides in Seattle commissioned by Seattle Public Utilities identified the following common types of landslides in the region (see Figures 12-1, 12-2 and 12-3):

- High Bluff Peel-Off—Block falls of soil from high bluffs (primarily along the near-vertical cliffs of Puget Sound).
- Deep-Seated Landslides—Deep, rotational or translational sliding and slumping caused by groundwater pressures within a hillside.
- Shallow Slides—Shallow rapid sliding of the outer surface of a hillside slope, sometimes also resulting in a debris flow.

Shallow slides are the most common and the most probable in the Puget Sound area. These occur particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types. Water is involved in nearly all cases; human influence was identified in more than 80 percent of the reported slides.

Many of the major river valleys in the Puget Sound region are bordered by steep slopes that are highly susceptible to landslides. Erosion by moving surface water is the dominant erosion process in the Puget Sound region; however, unmanaged stormwater runoff, as well as clearing, grading, excavation and filling during construction and deforestation, also contribute to increased erosion. Erosion can result in loss of support to structures and facilities. The sediments can enter man-made or natural drainages, possibly causing overflows or flooding. The sediments also can affect water quality and adversely affect stream and riparian habitat.

Historically, landslides in King County have occurred in erosion-prone areas. If surface water runoff is not managed properly, these areas can become unstable. Steep slopes and landslide hazard areas can also be adversely affected by changes in the hydrogeologic regime caused by natural fluctuations or by increases in groundwater elevations caused by stormwater or wastewater infiltration. The potential impacts for steep slopes are the same as for erosion and landslide hazard areas.

12.3.1 Past Events

Landslides have been a significant problem in Puget lowland areas for many years, and several landslides occur every year during the rainy season. The Washington Department of Natural Resources Division of Geology and Earth Resources identified recent landslide data as provided in Table 12-1.

TABLE 12-1.
KING COUNTY LANDSLIDE HISTORY

Event/Date	Area	King County Public Damage
1972 Severe Weather	King County	$1.8 Million
1996-1997 Severe Weather	King County	$9.0 Million
2001 Nisqually Earthquake	Maple Valley	$1.71 Million
2006 Winter Storms	Mercer Island	34 documented slides. Value of $ loss not available
2007 Winter Storms	King County	5 documented slides. Value of $ loss not available
2009 Winter Storms	King County	51 documented slides based upon preliminary data. Value of $ loss not available

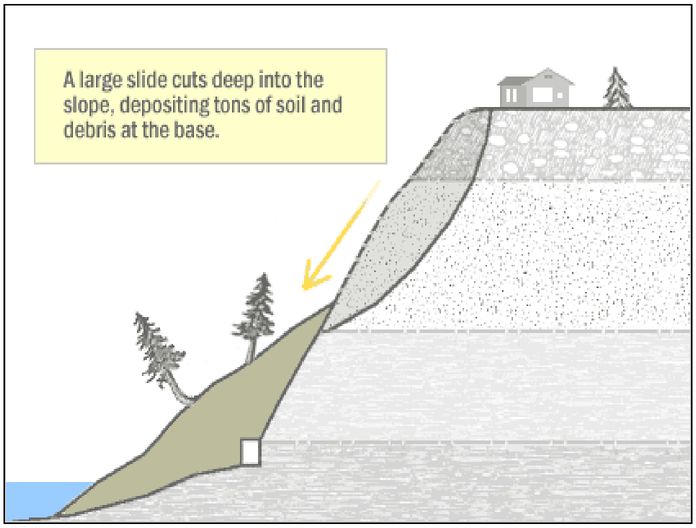


Figure 12-1. High Bluff Peel-Off

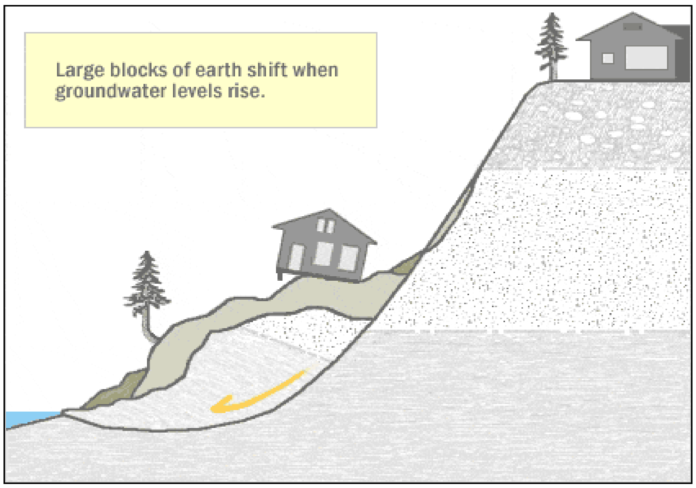


Figure 12-2. Deep-Seated Landslide

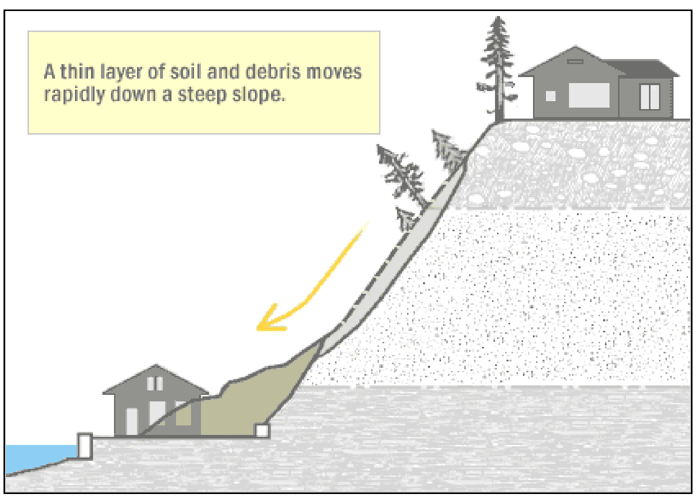


Figure 12-3. Shallow Slide

Storms triggered significant numbers of landslides in 1972, 1986, 1990, 1996, 1997, 2006, 2007 and 2009. Many of the 1997 landslides were in the same general areas as the 1972 landslides. Very heavy rains in King County resulted in significant slides and associated damages in 1972. Seventy percent of the slides occurred within two days after the heavy rains.

The most widespread landslide activity was secondary to the severe winter storm events that hit the Puget Sound region from December 1996 through March 1997. Unusually heavy snow and rain in King County resulted in slides that damaged or destroyed 8,000 homes. Over 100 slides were recorded in King County over a two-month period. Particularly hard hit areas were slopes on Magnolia Hill in Seattle, areas along Interstate-5, and Vashon Island.

Two weather events in November and December of 1998 caused a number of small slides in King County. Landslides along Interstate-5 near SeaTac Airport briefly closed portions of the northbound freeway. Evidence of slide activity can still be seen along the eastern side of Interstate-5 from King County Airport to the Interstate-90 interchange where portions of hillside collapsed carrying trees and debris downhill, but just short of impacting Interstate-5.

12.3.2 Location

Map 12-1 shows the landslide hazard areas in King County as delineated for the King County Sensitive Areas Ordinance. The basis of the mapping is as follows:

- Any area with a combination of:
  - Slopes greater than 15 percent
  - Impermeable soils (typically silt and clay) frequently interbedded with granular soils (predominantly sand and gravel)
  - Springs or groundwater seepage
- Any area that has shown movement during the Holocene epoch (from 10,000 years ago to present), or that is underlain by mass wastage debris of that epoch
- Any area potentially unstable as a result of rapid stream incision, stream bank erosion or undercutting by wave action
- Any area that shows evidence of, or is at risk from, snow avalanches
- Any area located on an alluvial fan, presently subject to or potentially subject to inundation by debris flows or deposition of stream-transported deposits.

The recognition of ancient dormant mass movement sites is important in the identification of areas susceptible to flows and slides because they can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding.

12.3.3 Frequency

Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods or wildland fires, so the frequency of landslides is related to the frequency of these other hazards. In the King County planning area, landslides typically occur during and after major storms. The preponderance of landslides occurs in January after the water table has risen during the wetter months of November and December. Recent events occurred during the winter storms of 2009, 2006, and 2003.

12.3.4 Severity

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost of about $1.5 billion. Since 1972, landslides have caused more that $10 million in damage in King County.

12.3.5 Warning Time

Mass movements can occur suddenly or slowly. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. Generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together.

12.4 SECONDARY HAZARDS

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay emergency response or commercial, public and private transportation. This could result in economic losses for businesses. Utility poles on slopes can be knocked over, resulting in losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents.

Landslides can result in short-term damage to rivers or streams, potentially harming water quality, fisheries and spawning habitat. For example, the Nisqually earthquake triggered a landslide that changed the course of the Cedar River near Ron Regis Park in Renton. Despite the initial adverse impacts on habitat and water quality, this reach is now some of the best habitat on the river because of the increased large wood, and the resulting habitat complexity.

12.5 CLIMATE CHANGE IMPACTS

Climate change will impact storm patterns in Washington. This changing of the hydrograph means that the probability of more frequent, intense storms with varying duration will increase. Increase in global temperature will also affect the snowpack and its ability to hold and store water. Additionally, warming temperatures will increase the occurrence and duration of droughts, which will increase the probability of wildland fire, which impacts the vegetation that helps to support steep slopes. All of these factors working in unison would increase the probability for landslide occurrences within the planning area.

12.6 EXPOSURE

12.6.1 Population

Population could not be examined by landslide hazard area because census block group areas do not coincide with the risk areas. However, the planning committee was able to create a population estimate using the structure count of buildings within the landslide hazard areas and applying the census value for persons per household for King County (2.39). Using this approach, it is estimated that the population living with the landslide risk areas of the county is 34,160. This approach could understate the exposure by as much as a factor of two, so it is reasonable to assume that the exposed population is between 30,000 and 60,000. This represents less that 5 percent of the total population for the county.

12.6.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for exposure of general property to the landslide hazard.

12.6.3 Critical Facilities and Infrastructure

Historically, landslides have had significant impacts on flood control facilities in King County. Landslides along stream corridors can relocate or block stream channels, as occurred along the Cedar River following the 2001 Nisqually Earthquake. The exposure analysis for the landslide hazard identified facilities in areas susceptible to landslides. The model distinguishes between levees and revetments; all other district facilities, such as buildings, are classified as “Other.” Table 12-2 lists exposed facilities and infrastructure by river basin. It is estimated that 2.2 miles of levees and revetments are in areas identified as susceptible to landslides. The estimated replacement cost for these facilities exceeds $23.4 million.

12.6.4 Environment

Environmental problems as a result of mass movements can be numerous. Landslides fall into streams and significantly impact fish and wildlife habitat, as well as affecting water quality.

12.7 VULNERABILITY

12.7.1 Population

No population vulnerability analysis was prepared for the landslide hazard.

12.7.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for vulnerability of general property to the landslide hazard.

TABLE 12-2.
CRITICAL FACILITIES IN AREAS SUSCEPTIBLE TO LANDSLIDES

River Basin	Facility Type	Length of Facility Exposed (feet)	Replacement cost[a]
Lower Snoqualmie	Revetment	4,226	$8,452,946
Sammamish	Other	1,305	$2,610,037
	Revetment	218	$435,772
Cedar	Levee	1,164	$2,328,495
	Revetment	2,890	$5,780,601
Green	Levee	895	$1,789,593
	Revetment	930	$1,860,683
White	Levee	107	$214,242
Total		**11,735**	**$23,472,369**

a. Replacement cost determined using $2,000/lineal foot based upon county data from past projects

12.7.3 Critical Facilities and Infrastructure

Loss estimates for the landslide hazard are not based on modeling using damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the replacement cost of the exposed facilities. Damage in excess of 50 percent is considered to be substantial under most industry standards. Table 12-3 lists the loss estimates for district facilities exposed to the areas susceptible to landslide hazards.

TABLE 12-3.
KING COUNTY FLOOD CONTROL DISTRICT FACILITIES VULNERABLE TO LANDSLIDE HAZARD

River Basin	Facility Type	Replacement Cost	10% Damage	30% Damage	50% Damage
Lower Snoqualmie	Revetment	$8,452,946	$845,295	$2,535,884	$4,226,473
Sammamish	Other	$2,610,037	$261,004	$783,011	$1,305,019
	Revetment	$435,772	$43,577	$130,732	$217,886
Cedar	Levee	$2,328,495	$232,850	$698,549	$1,164,248
	Revetment	$5,780,601	$578,060	$1,734,180	$2,890,301
Green	Levee	$1,789,593	$178,959	$536,878	$894,796
	Revetment	$1,860,683	$186,068	$558,205	$930,341
White	Levee	$214,242	$21,424	$64,272	$107,121
Total		**$23,472,369**	**$2,347,237**	**$7,041,711**	**$11,736,185**

12.7.4 Environment

The environment vulnerable to landslide hazard is the same as the environment exposed to the hazard.

12.8 FUTURE TRENDS IN DEVELOPMENT

King County’s population increased by approximately 9 percent between 2000 and 2009, and has averaged 1.19 percent annual growth since 1990. It is anticipated that King County will continue to grow at similar rates in the near future. As a special purpose district with a principle mission to manage flood risk, King County Flood Control District has a limited role in mitigating increased landslide risk associated with future development. The district’s focus for landslide risk mitigation will be to manage the specific facilities for which it has responsibility. As facilities are upgraded or replaced, the district will have the opportunity to incorporate landslide risk reduction into the design of the improvements.

District funds are based on a countywide levy tax. As the population increases and additional homes are built to house the increased population, the district’s revenue increases to reflect new construction and a maximum annual increase of 1 percent, under the provisions of Initiative 747. While this could increase total revenues over time, it is unlikely to keep pace with inflation over the long term.

12.9 SCENARIO

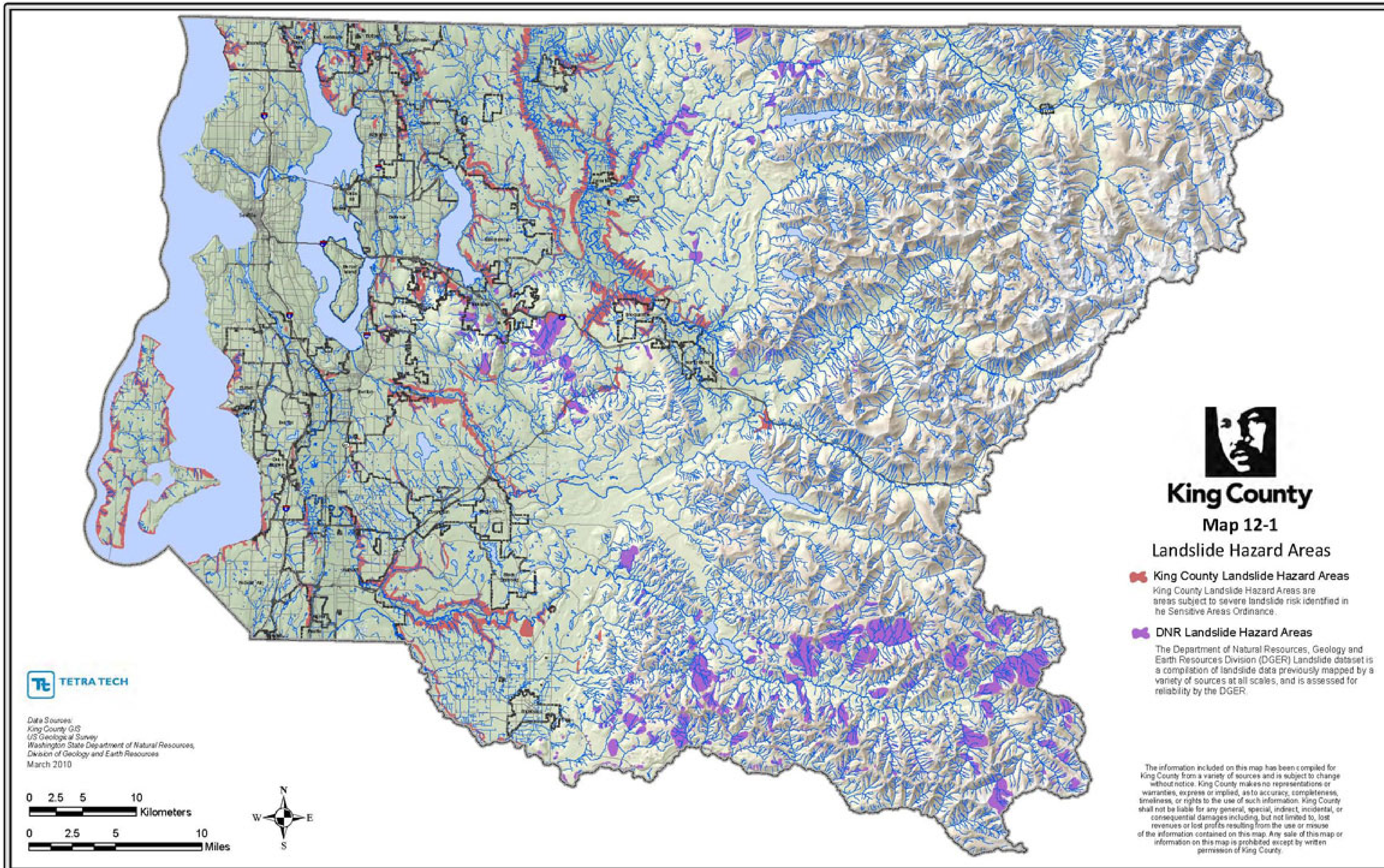
Mass movements are becoming more of a concern as development moves outside of city centers and into less developed areas. Major mass movements in King County occur as a result of soil conditions that have been affected by severe storms, groundwater or human development. After heavy rains from November to December, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. As rains continue, the groundwater table rises, adding to the weakening of the slope. Gravity, poor drainage, a rising groundwater table and poor soil exacerbate hazardous conditions.

A mass movement event is most likely to occur during late winter when the water table is high. A short intense storm could cause the saturated soil to move, resulting in landslides. Most mass movements would be isolated events, affecting specific areas. The worst-case scenario in King County would generally correspond with a severe storm with heavy rain that causes flooding. It is probable that district facilities can and will be impacted by landslides as they have been in the past.

12.10 ISSUES

Important issues associated with landslides on King County Flood Control District facilities include but are not limited to the following:

- The data and science regarding the mapping and assessment of landslide hazards is constantly evolving. As new data and science become available, assessments of landslide risk should be re-evaluated.
- The impact of climate change on landslides is uncertain. If climate change impacts atmospheric conditions, the exposure to landslide risks in King County are likely to increase.
- Landslides may result in loss of water quality to the environment and for drinking purposes due to increased sediment delivery into surface waterways.


King County
Map 12-1
Landslide Hazard Areas
King County Landslide Hazard Areas
King County Landslide Hazard Areas are areas subject to severe landslide risk identified in he Sensitive Areas Ordinance.
DNR Landslide Hazard Areas
The Department of Natural Resources, Geology and Earth Resources Division (DGER) Landslide dataset is a compilation of landslide data previously mapped by a variety of sources at all scales, and is assessed for reliability by the DGER.
TETRA TECH
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
March 2010
0 2.5 5 10 Kilometers
0 2.5 5 10 Miles
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CHAPTER 13.
SEVERE WEATHER

13.1 SEVERE WEATHER DEFINED

The following definitions apply in the discussion of severe weather hazards:

- **Freezing Rain**—The result of rain occurring when the temperature is below the freezing point. When this occurs, the rain will freeze on impact and will result in a layer of glaze ice up to an inch thick over exposed surfaces. In a severe ice storm, an evergreen tree 60 feet high and 30 feet wide can be burdened with up to six tons of ice, creating a serious threat to power and telephone lines and transportation routes.
- **Severe Local Storm**—"Microscale" atmospheric systems, including tornadoes, thunderstorms, windstorms, ice storms and snowstorms. Typically, major impacts from a severe storm are on transportation infrastructure and utilities. These storms may cause a great deal of destruction and even death, but their impact is generally confined to a small area.
- **Thunderstorm—**Typically 15 miles in diameter and lasting about 30 minutes, thunderstorms are underrated hazards. Lightning, which occurs with all thunderstorms, is a serious threat to human life. Heavy rains over a small area in a short time can lead to flash flooding. Strong winds, hail and tornadoes are also dangers associated with thunderstorms.
- **Tornado**—Tornadoes are funnel clouds of varying sizes that generate winds up to 500 miles per hour. A tornado is formed by the turbulent mixing of layers of air with contrasting temperature, moisture, density and wind flow. The mixing layers of air account for most tornadoes occurring in April, May and June, when cold, dry air meets warm, moister air moving up from the south. They can affect an area up to three-quarters of a mile wide, with a path of varying length. Tornadoes can come from lines of cumulonimbus clouds or from a single storm cloud. They are measured using the Fujita Scale ranging from F0 to F6.
- **Windstorm**—A storm featuring violent winds. Southwesterly winds are associated with strong storms moving onto the coast from the Pacific Ocean. Southern winds parallel to the coastal mountains are the strongest and most destructive winds. Windstorms tend to damage ridgelines that face into the winds.
- **Winter storm** – The National Weather Service defines a winter storm as having significant snowfall, ice, and/or freezing rain; the quantity of precipitation varies by elevation. Heavy snowfall is 4 inches or more in a 12-hour period, or 6 inches or more in a 24-hour period in non-mountainous areas; and 12 inches or more in a 12-hour period or 18 inches or more in a 24-hour period in mountainous areas.

13.2 GENERAL BACKGROUND

Washington has a predominantly marine climate west of the Cascade Mountains. Two key factors affect the state's climate:

- **Mountain ranges**—The Olympic Mountains and the Cascade Mountains affect rainfall. The first major release of rain in weather systems coming off the Pacific Ocean occurs along the west slopes of the Olympics, and the second is along the west slopes of the Cascade Range. Air warms and dries as it descends along the eastern slopes of the Cascades, resulting in near desert conditions in the lowest section of the Columbia Basin in eastern Washington.

- **Semi-permanent high- and low-pressure areas over the North Pacific Ocean**—During summer and fall, the circulation of air around a high-pressure area over the North Pacific brings a prevailing westerly and northwesterly flow of comparatively dry, cool and stable air into the Pacific Northwest. As the air moves inland, it becomes warmer and drier, resulting in a dry season. In the winter and spring, the high pressure is further south and low pressure prevails in the Northeast Pacific. Circulation of air around both pressure centers brings a prevailing southwesterly and westerly flow of mild, moist air into the Pacific Northwest. Condensation occurs as the air moves inland over the cooler land and rises along the windward slopes of the mountains. This results in a wet season beginning in late October or November, reaching a peak in winter, and gradually decreasing by late spring.

West of the Cascade Mountains, summers are cool and relatively dry while winters are mild, wet and generally cloudy. Measurable rainfall occurs on 150 days each year in interior valleys and on 190 days in the mountains and along the coast. Thunderstorms occur up to 10 days each year over the lower elevations and up to 15 days over the mountains. Damaging hailstorms are rare in Western Washington. During July and August, the driest months, two to four weeks can pass with only a few showers; however, in December and January, the wettest months, precipitation is frequently recorded on 25 days or more each month. Snowfall is light in the lower elevations and heavy in the mountains. During the wet season, rainfall is usually of light to moderate intensity and continuous over a long period rather than occurring in heavy downpours for brief periods; heavier intensities occur along the windward slopes of the mountains.

The strongest winds are generally from the south or southwest and occur during fall and winter. In interior valleys, wind velocities reach 40 to 50 mph each winter, and 75 to 90 mph a few times every 50 years. The highest summer and lowest winter temperatures generally occur during periods of easterly winds.

13.3 HAZARD PROFILE

13.3.1 Past Events

Table 13-1 summarizes severe weather events in King County since 1950, as recorded by the National Oceanic and Atmospheric Administration. In addition to the events listed, the most notable windstorms in King County occurred in 1976, 1979, 1981, 1993 and 2006. Power outages from the Inauguration Day windstorm of January 20, 1993 lasted from three to five days. The most powerful windstorm since the Inauguration Day Storm of 1993 was in December 2006, with gusts up to 70 mph in the Puget Sound basin. Severe snowstorms occurred in the planning area in 1969, 1971, 1980 and 1990.

13.3.2 Location

Severe weather events have the potential to happen anywhere in the planning area. Communities in low-lying areas next to streams or lakes are more susceptible to flooding. Wind events are most damaging to areas that are heavily wooded. Maps 13-1, 13-2, 13-3 and 13-4 illustrate severe weather conditions for the King County planning Area.

13.3.3 Frequency

According to the Washington State Enhanced Hazard Mitigation Plan, King County experiences a high wind event at least once per year. The plan indicates a 70 percent probability that King County will have a severe winter storm at least once every 2 years.

**TABLE 13-1.
SEVERE WEATHER EVENTS IN KING COUNTY SINCE 1958**

Date	Type	Deaths or Injuries	Property Damage
03/03/1956	Thunderstorm Wind (80 knots)	0	0
09/28/1962	Tornado (F1)	0	$250,000
08/18/1964	Tornado (F0)	0	0
12/12/1969	Tornado (F3)	0	$250,000
12/23/1969	Thunderstorm Wind	0	0
12/22/1971	Tornado (F0)	0	$25,000
06/08/1972	Hail (1.50 in.)	0	0
10/22/1985	Thunderstorm Wind	0	0
05/17/1989	Thunderstorm Wind	0	0
08/23/1993	Lightning	1	0
Description: *A jogger struck by lightning while running in the 5100 block of West Lake Sammamish Parkway never regained consciousness and died 17 hours later.*			
03/21/1994	High Winds	0	0
11/01/1994	High Winds	0	0
Description: *Winds were reported 45 to 55 mph in some areas along the Puget Sound with numerous power outages due to fallen tree limbs on power lines.*			
12/30/1994	High Wind	0	0
01/08/1995	Freezing Rain	0	0
Description: *Several reports of icy roads due to early morning, freezing rain were received from the east side of the county were several cars slid off the roads due to slippery conditions*			
12/29/1996	Ice/snow/rain	0	$31.5 M
Description: *The December 26—31 ice/snow/rain storm caused about $315 million in insured and uninsured damage (in all of Washington). The storms directly or indirectly claimed 16 lives and sparked a state of emergency in 30 counties. Seattle normally averages 1.44 inches of precipitation between Dec. 26 and Jan 2. It received 8.35 inches during those eight days. The total number of customers without power at one time was nearly 300,000 and some people went a week without power. The damage affected people for weeks.*			
04/03/1997	Lightning	0	0
Description: *A woman holding an umbrella was struck by lightning.*			
08/03/1999	Lightning	0	$650,000
Description: *Over 1000 lightning strikes were recorded in a four-hour period. One man was struck by lightning while standing under a tree, and another man while standing in water next to his boat. At its peak, the storm knocked out power to about 20,000 customers.*			
12/14/2006	High Wind (60-75 mph)	0	$750,000
Description: *In western Washington, peak winds reached 80 to 90 mph along the coast and elsewhere 60 to 75 mph. A few locations had gusts as high 85 mph in the interior. Mountain areas recorded peak wind speeds reached in excess of 100 mph, including 113 mph at Chinook Pass and 100 mph at Sunrise in Mt Rainier National Park. The windstorm, the strongest since the 1993 Inauguration Day Wind Storm, blew down thousands of trees and knocked power out to close to 1.5 million customers in western Washington. The strong winds damaged major transmission lines, power poles and other power utility infrastructure. Trees also fell onto houses, street signs, streetlights, parked cars, fences, railings and rooftops.*			
12/2008	Record Snowfall	0	Unknown
Description: *Record or near-record snowfall impacted most of Western Washington*			

13.3.4 Severity

The most common problems associated with severe storms are immobility and loss of utilities. Fatalities are uncommon, but can occur. Roads may become impassable due to flooding, downed trees, ice or snow, or a landslide. Power lines may be downed due to high winds or ice accumulation and other services, such as water or phone, may not be able to operate without power. Lightning can cause severe damage and injury. Snowfall can cause dangerous roadways and collapse of structures due to heavy snow on roofs.

Tornadoes are the smallest but potentially most dangerous of local storms, though they are not common in King County. If a major tornado were to strike a populated area, damage could be widespread. Businesses could be forced to close for an extended period or permanently, fatalities could be high, many people could be homeless for an extended period, and routine services such as telephone or power could be disrupted. Buildings may be damaged or destroyed. Livestock are commonly the victims of a tornado.

Windstorms are a frequent problem in King County and have been known to cause substantial damage. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher.

The effects of an ice storm or snowstorm are downed power lines and trees and a large increase in traffic accidents. These storms can cause death by exposure, heart failure due to shoveling or other strenuous activity, traffic accidents (over 85 percent of ice storm deaths are caused by traffic accidents), and carbon monoxide poisoning. These storms also have the potential to cause large losses among livestock. Livestock losses are caused primarily by dehydration rather than cold.

13.3.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

13.4 SECONDARY HAZARDS

The most significant secondary hazards associated with severe local storms are floods, falling and downed trees, landslides and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails. These secondary impacts are those that pose the most cause for concern to the King County Flood Control District.

13.5 CLIMATE CHANGE IMPACTS

Climate change presents a significant risk management challenge for dealing with extreme weather. The frequency of extreme weather events has increased steadily over the last century. The number of weather-related disasters during the 1990s was four times that of the 1950s, and cost 14 times as much in economic losses. Historical data shows that the probability for severe weather events increases in a warmer climate (see Figure 13-1).

Warmer climates could have significant impacts on the jet stream, which would impact the planning area’s susceptibility to severe wind events and winter storms. The changing hydrograph caused by climate change could have a significant impact on the intensity, duration and frequency of storm events. All of these impacts could have significant economic consequences.

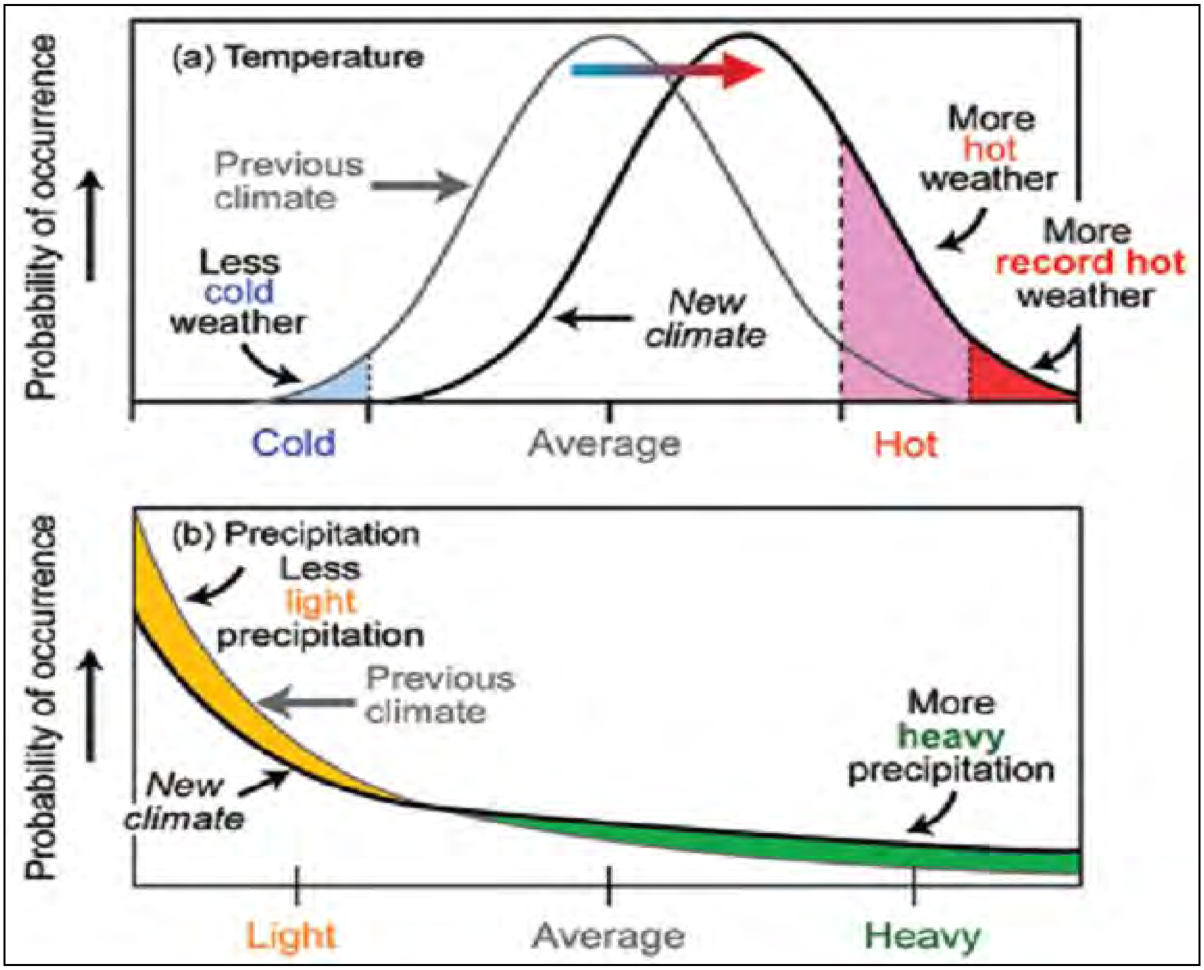


Figure 13-1. Severe Weather Probabilities in Warmer Climates

13.6 EXPOSURE

13.6.1 Population

It can be assumed that the entire King County planning area is exposed to severe weather events. Certain areas are more exposed due to geographic location and localized weather patterns. Populations living at higher elevations with large stands of trees or power lines may be more susceptible to wind damage and black out, while populations living in low-lying areas are at risk for flooding.

13.6.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for exposure of general property to the severe weather hazard.

13.6.3 Critical Facilities and Infrastructure

The district has maintenance responsibility for over 500 facilities that are critical to district operations. All of these facilities are likely exposed to severe weather.

13.6.4 Environment

Severe storm events can drastically affect the physical environment, changing natural landscapes. Natural habitats such as streams and trees are exposed to the elements during a severe storm and risk major damage and destruction. Prolonged rains can saturate soils and lead to slope failure. Flooding caused by severe weather can cause stream channel migration. Additionally, snowmelt after snowstorms can cause riverine flooding, which has the potential to damage riparian habitat.

13.7 VULNERABILITY

There are currently no loss estimation tools with uniform damage functions for severe weather events. This can be attributed to the variety of impacts that severe weather events generate. Also, the severity of severe weather events varies by location. Since secondary effects of severe weather events include flooding, landslides or even wildland fires in drier climates, the vulnerability assessments under those hazards can provide emergency managers a gage of the economic impact of severe weather events. For this section, the vulnerability to severe weather events is discussed qualitatively.

13.7.1 Population

Vulnerable populations are the elderly, low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe weather events and could suffer more secondary effects of the hazard.

13.7.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for vulnerability of general property to the severe weather hazard.

13.7.3 Critical Facilities and Infrastructure

Flood and landslide hazards are secondary impacts of severe weather events. Generally, the types of facilities the district maintains are not considered vulnerable to windstorm events. District facilities that rely on electrical power for operations, such as pump stations or the flood warning center, could experience some functional down time due to power outages associated with wind storm events. However, these types of facilities typically have sufficient redundancy for backup power to not be considered a major vulnerability.

Landslides that block roads are caused by heavy prolonged rains. Road blockages could inhibit district personnel from gaining access to facilities during severe weather events to monitor facility function, which is an important emergency response function of the district.

13.7.4 Environment

The environment vulnerable to the severe weather hazard is the same as the environment exposed to the hazard.

13.8 FUTURE TRENDS IN DEVELOPMENT

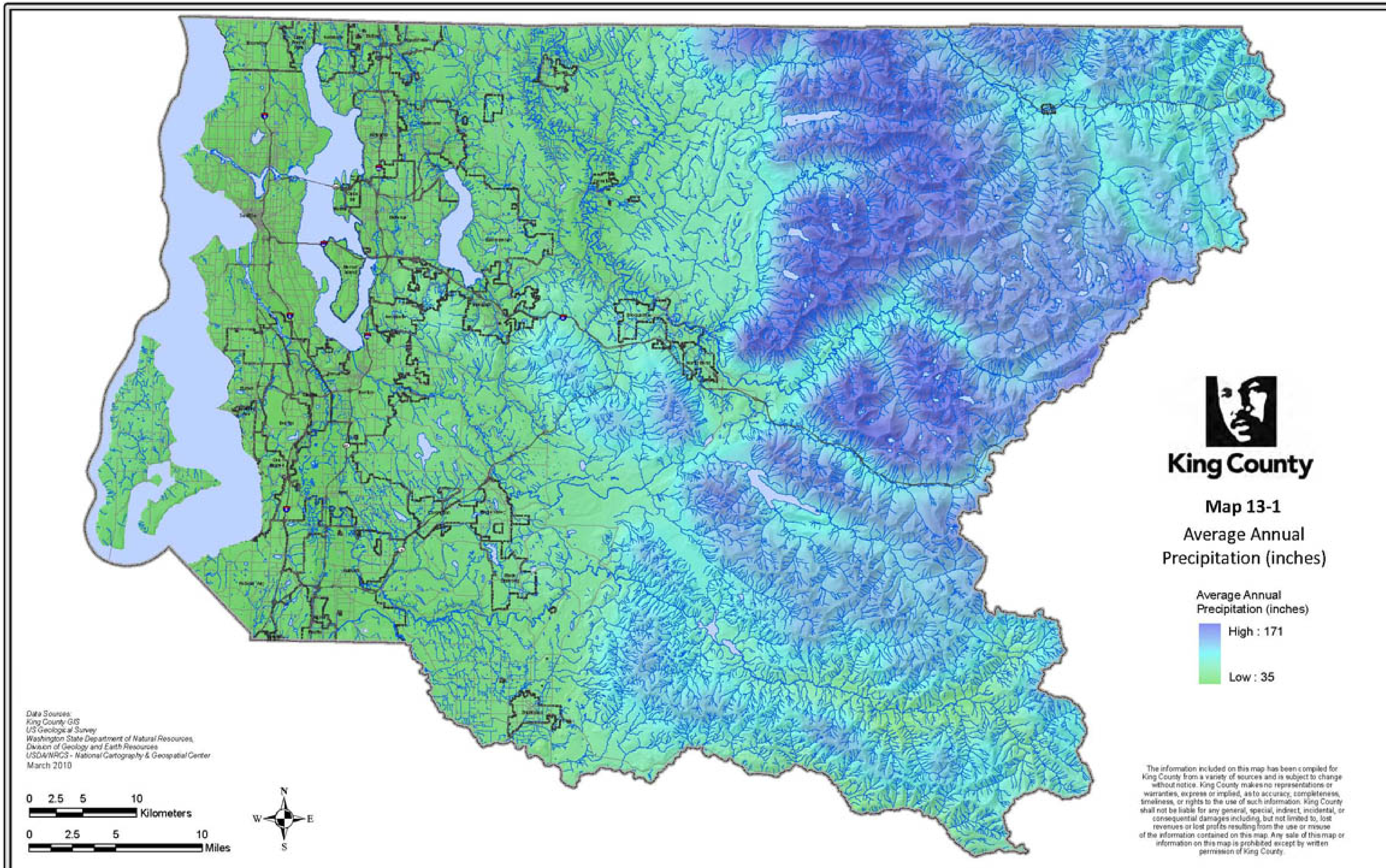
King County's population is anticipated to maintain the steady rate of growth it has experienced over the last 20 years. As the population increases and additional homes are built to house the increased population, the district's revenue increases to reflect new construction and a maximum annual increase of 1 percent, under the provisions of Initiative 747. With over 500 facilities under its jurisdiction, many of which exceeded their functional project life, the demands for these resources will increase as well. Future development within King County could increase the impacts of flood related events such as severe weather on district facilities. Environmental issues such as salmon recovery and clean water initiatives will also have significant impacts on how the district will manage this future growth. These issues may have significant impacts on the way the district operates and maintain its facilities

13.9 SCENARIO

A worst-case event would involve prolonged high winds during an extremely wet rain/snowstorm accompanied by freezing temperatures, followed by warmer weather and continued rain. Such an event would have both short-term and long-term effects. Initially, schools and roads would be closed due to flooding, downed tree obstructions, and downed power lines. Power outages would be common throughout the county. Later, as the weather warms and rains continue while snow melts, the sudden runoff could produce flooding, overtopped culverts with ponded water on roads, and landslides on steep slopes. Flooding and landslides could further obstruct roads, bridges, and river systems, significantly impacting district facilities.

13.10 ISSUES

All major issues concerning severe weather events for the King County Flood Control District are discussed under the flood and landslide hazards of this plan.



King County
Map 13-1
Average Annual Precipitation (inches)
Average Annual Precipitation (inches)
High : 171
Low : 35
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
USDA/NRCS - National Cartography & Geospatial Center
March 2010
0 2.5 5 10 Kilometers
0 2.5 5 10 Miles
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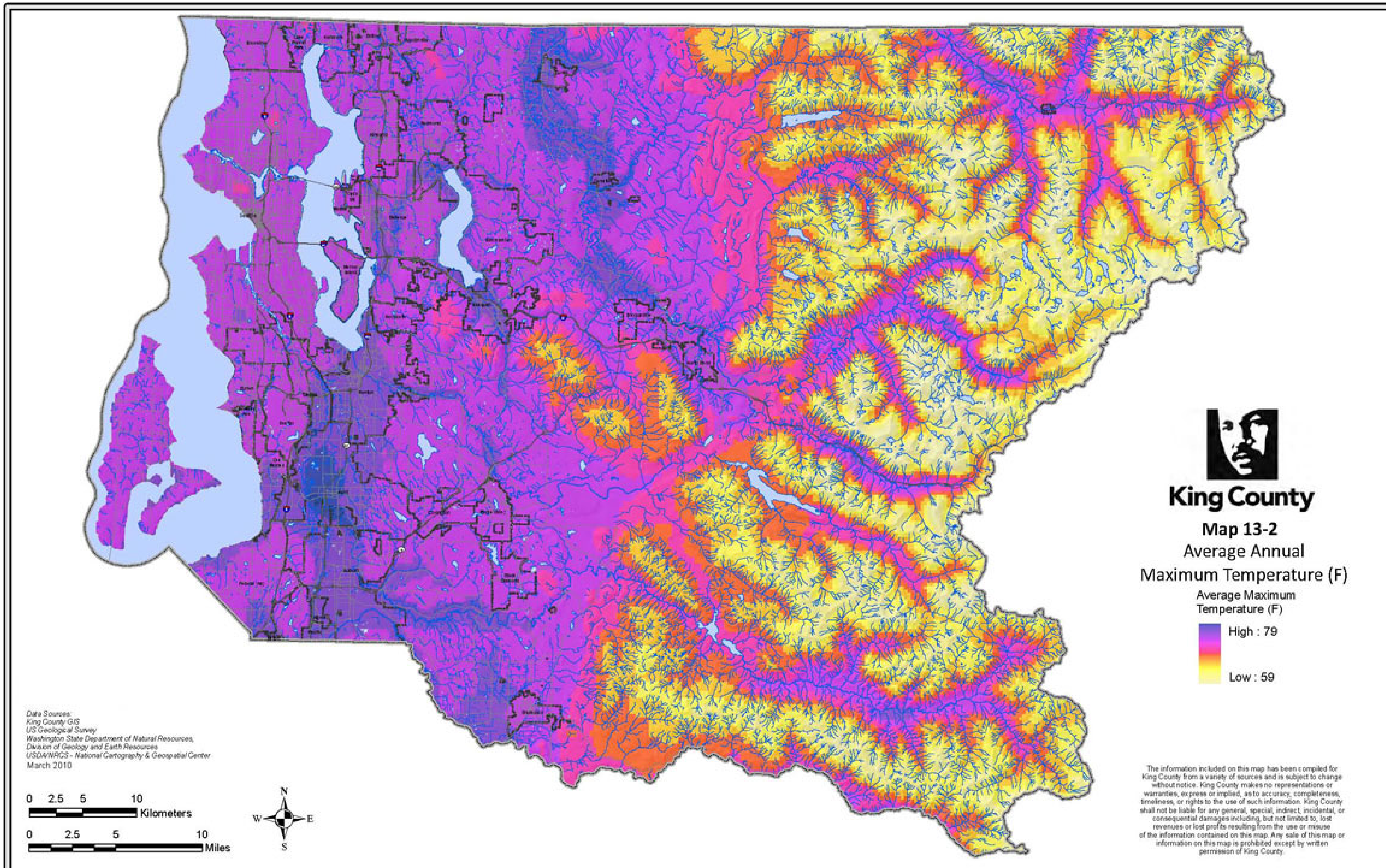
King County
Map 13-2
Average Annual
Maximum Temperature (F)
Average Maximum
Temperature (F)
High : 79
Low : 59
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
USDA/NRCS - National Cartography & Geospatial Center
March 2010
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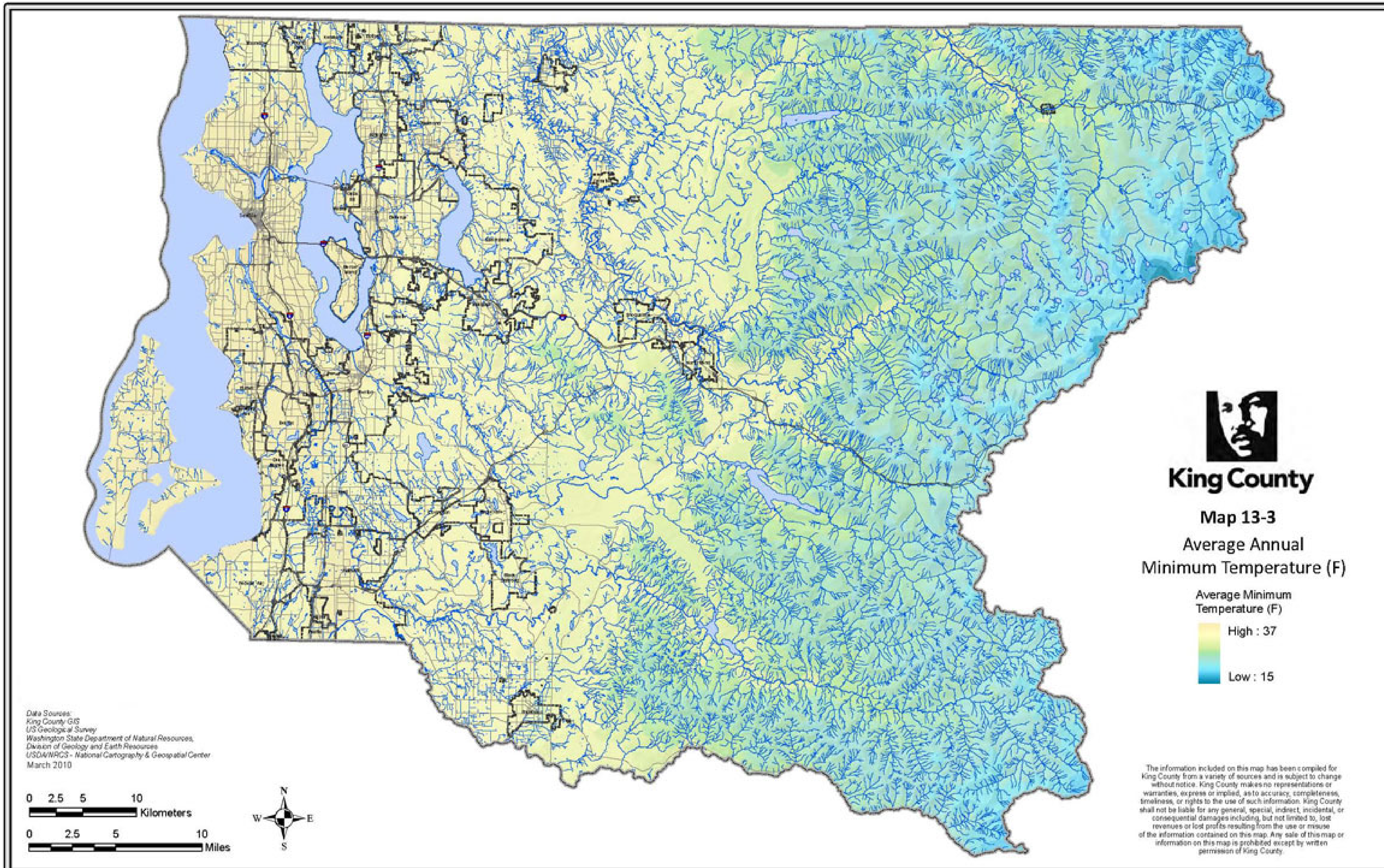

King County
Map 13-3
Average Annual
Minimum Temperature (F)
Average Minimum
Temperature (F)
High : 37
Low : 15
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
USDA/NRCS - National Cartography & Geospatial Center
March 2010
0 2.5 5 10
Kilometers
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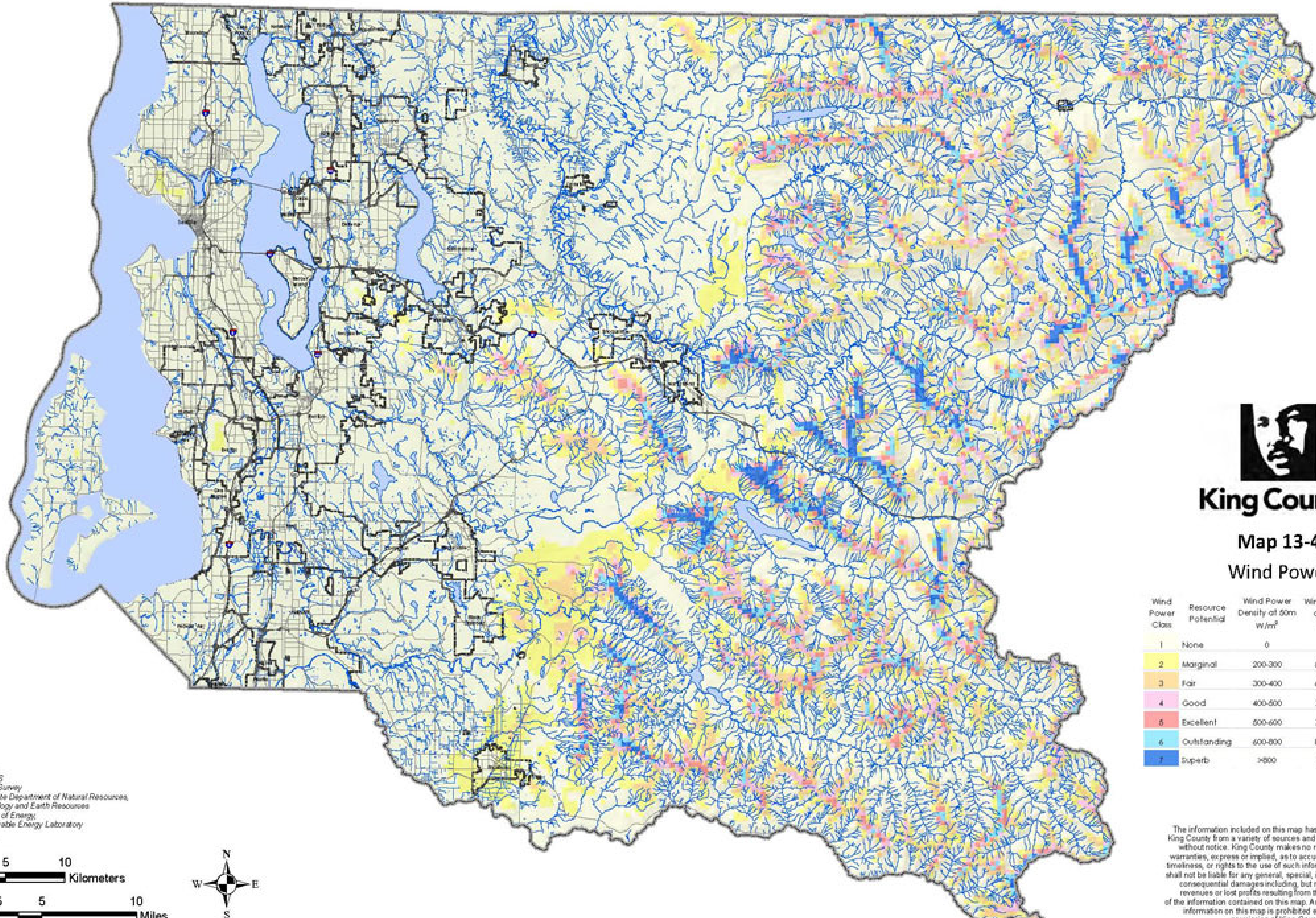


King County

Map 13-4
Wind Power

Wind Power Class	Resource Potential	Wind Power Density at 50m W/m²	Wind Speed at 50m m/s	Wind Speed at 50m mph
1	None	0	0	0
2	Marginal	200-300	5.6-6.4	12.5-14.3
3	Fair	300-400	6.4-7.0	14.3-15.7
4	Good	400-500	7.0-7.5	15.7-16.8
5	Excellent	500-600	7.5-8.0	16.8-17.9
6	Outstanding	600-800	8.0-8.8	17.9-19.7
7	Superb	>800	>8.8	>19.7

Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources, Division of Geology and Earth Resources
US Department of Energy, National Renewable Energy Laboratory

March 2010

CHAPTER 14.
VOLCANO

14.1 VOLCANO DEFINED

The following definitions apply in the discussion of volcano hazards:

- **Ash Fall**—Volcanoes can erupt lavas so thick and charged with gases that they explode into ash rather than flow.
- **Lahars**—Lahars are rapidly flowing mixtures of water and rock debris that originate from volcanoes. While lahars are most commonly associated with eruptions, heavy rains, and debris accumulation, earthquakes may also trigger them. They may also be termed debris or mud flows.
- **Lava Flows**—Lava flows are normally the least hazardous threat posed by volcanoes. Cascades volcanoes are normally associated with slow moving andesite or dacite lava.
- **Stratovolcano**—The volcanoes in the Cascade Range are all stratovolcanoes. They are typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs and may rise as much as 8,000 feet above their bases.
- **Tephra:** The ash and the large volcanic projectiles that erupt from a volcano into the atmosphere are called tephra. The largest fragments (about 2 inches) fall back to the ground fairly near the vents, as close as a few feet and as far as 6 miles. The smallest fragments (ash) are composed of rock, minerals, and glass that are less than 1/8 inch in diameter and can fall back to the ground hundreds of miles from the source. Tephra plume characteristics are affected by wind speed, particle size, and precipitation.
- **Volcano**—A vent in the planetary crust from which magma (molten or hot rock) from the earth's core erupts.

14.2 GENERAL BACKGROUND

A volcano is a vent in the earth's crust through which magma, rock fragments, gases, and ash are ejected from the earth's interior. Over time, accumulation of these erupted products on the earth's surface creates a volcanic mountain. There are a wide variety of hazards related to volcanoes and volcanic eruptions. The hazards are distinguished by the different ways in which volcanic materials and other debris flow from the volcano. Molten rock that erupts from the volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles.

Washington has five major volcanoes in the Cascade Range—Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens and Mount Adams. Mount Hood, located in northern Oregon, can also affect the state. Figure 14-1 illustrates how Cascade volcanoes were formed.

Volcanoes can lie dormant for centuries between eruptions, and the risk they pose is not always apparent. When Cascade volcanoes erupt, high-speed avalanches of hot ash and rock called pyroclastic flows, lava flows, and landslides can devastate areas 10 or more miles away, while huge mudflows of volcanic ash and debris called lahars can inundate valleys more than 50 miles downstream. Falling ash from explosive eruptions, called tephra**,** can disrupt human activities hundreds of miles downwind, and drifting clouds of fine ash can cause severe damage to the engines of jet aircraft hundreds or thousands of miles away.

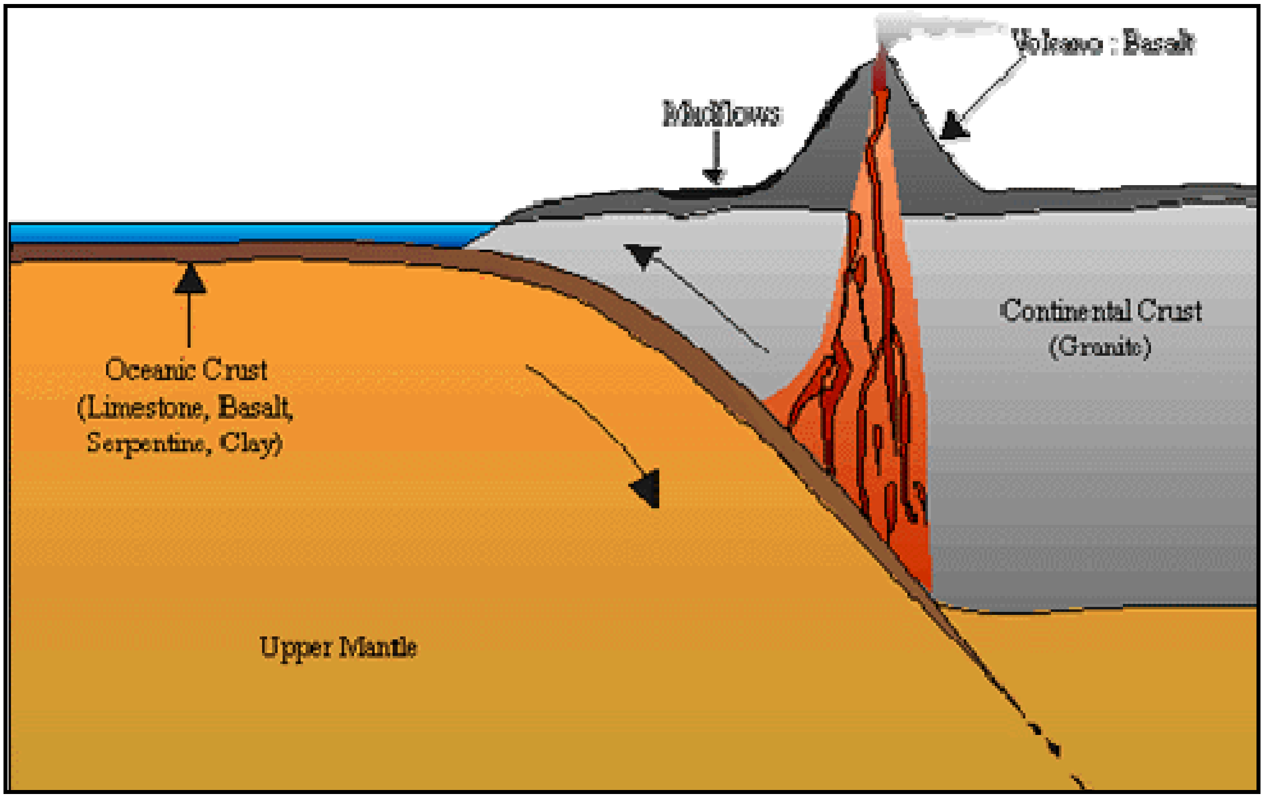


Figure 14-1. How Cascade Volcanoes Are Formed

14.3 HAZARD PROFILE

14.3.1 Past Events

Volcanic eruptions may only occur every few generations. Table 14-1 and Figure 14-2 summarize past eruptions in the Cascades and in the Puget Sound region.

TABLE 14-1.
PAST ERUPTIONS OF WASHINGTON VOLCANOES

Volcano	Number of Eruptions	Type of Eruptions
Mount Adams	3 in the last 10,000 years, most recent between 1,000 and 2,000 years ago	Andesite lava
Mount Baker	5 eruptions in past 10,000 years; mudflows have been more common (8 in same time period)	Pyroclastic flows, mudflows, ash fall in 1843.
Glacier Peak	8 eruptions in last 13,000 years	Pyroclastic flows and lahars
Mount Rainier	14 eruptions in last 9,000 years; also 4 large mudflows	Pyroclastic flows and lahars
Mount St. Helens	19 eruptions in last 13,000 years	Pyroclastic flows, mudflows, lava, and ash fall

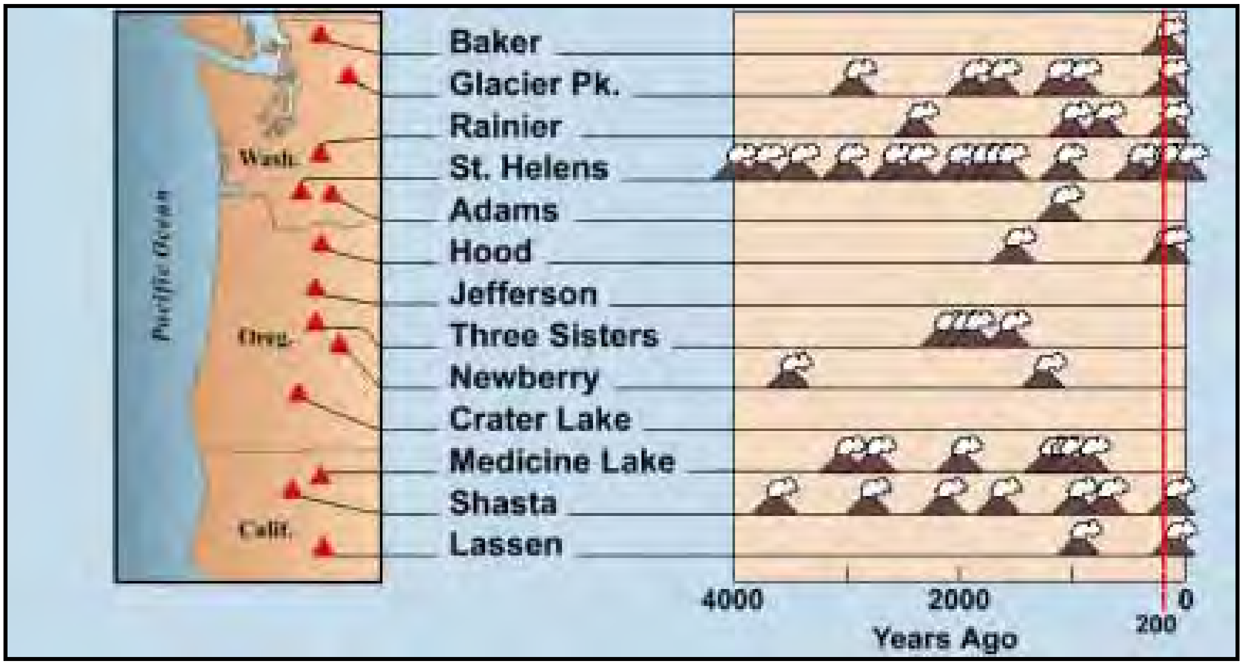


Figure 14-2. Cascade Range Eruptions in the Past 4,000 Years

The last major volcanic eruption in the Northwest was the explosion of Mount St. Helens on May 18, 1980. The eruption reduced the elevation of the mountain from 9,677 feet to 8,364 feet, buried the North Fork of the Toutle River under 23 square miles of volcanic material, and caused 57 human fatalities. Due to its distance, the lava and lahar flow from this eruption did not affect the King County area. The county was exposed to minor tephra fall, which was more of a curiosity than a hazard. Schools and businesses were closed for day or so, but no major disruptions or harm was done.

14.3.2 Location

The Cascade Range extends more than 1,000 miles from southern British Columbia into northern California and includes 13 potentially active volcanic peaks in the U.S. Figure 14-3 shows the location of the Cascade Mountains in Washington State. The closest volcanoes to King County are Mt. Rainer and Glacier Peak. The most hazardous volcanoes are those directly to the west and southwest (along the direction of prevailing winds). Lahar zones on Mt. Rainer impacting the southern portion of King County have been mapped by USGS. The zones are shown on Map 14-1.

14.3.3 Frequency

Washington's volcanoes will erupt again. There is a 1 in 500 probability that portions of two counties in the state will receive 4 inches or more of volcanic ash from any Cascades volcano in any given year, and a 1 in 1,000 probability that parts or all of three more counties will receive that quantity of ash. There is a 1 in 100 annual probability that small lahars or debris flows will impact river valleys below Mount Baker and Mount Rainier, and less than a 1 in 1,000 annual probability that the largest destructive lahars would flow down the slopes of Glacier Peak, Mount Adams, Mount Baker and Mount Rainier.

Eruptions in the Cascades have occurred at an average of 1 or 2 per century during the last 4,000 years. Mount St. Helens is the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years. Still, the probability of an eruption in any given year is extremely low. Figure 14-4 shows the annual probability of a tephra accumulation of about 4 inches. The probability of 4 inches or more of tephra accumulation affecting King County is approximately 0.02 percent in any given year.

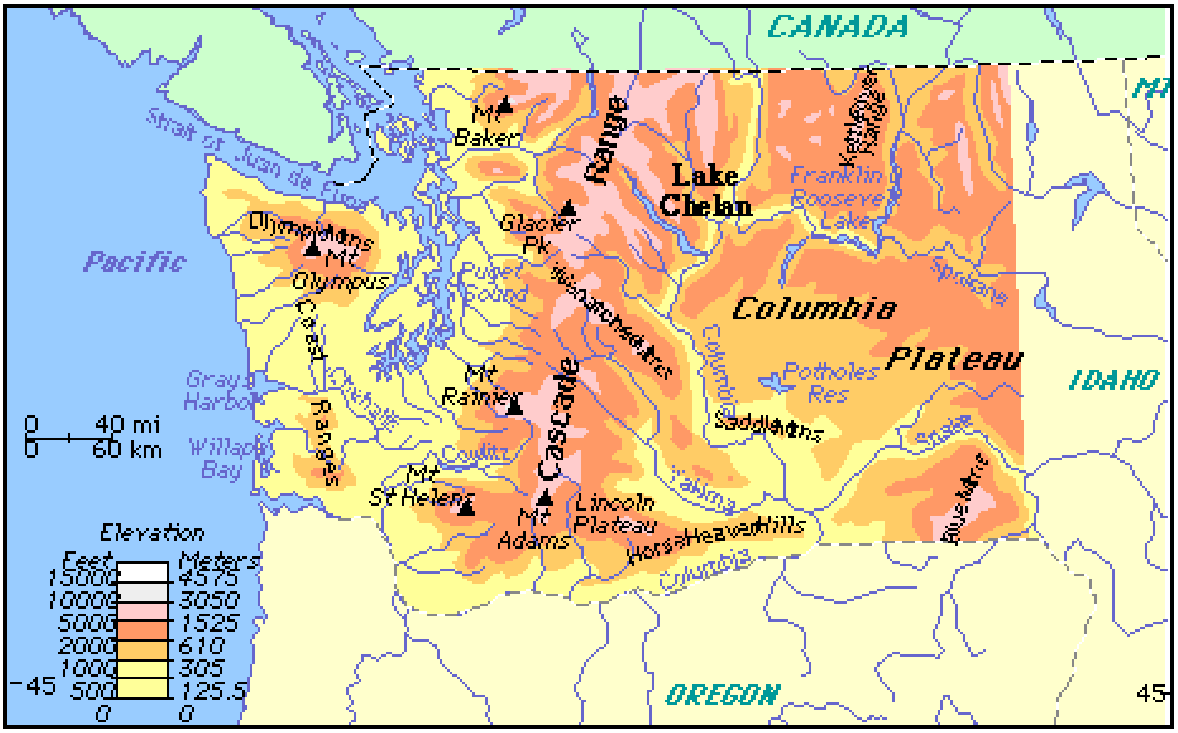


Figure 14-3. Location of Cascade Mountains and Volcanoes

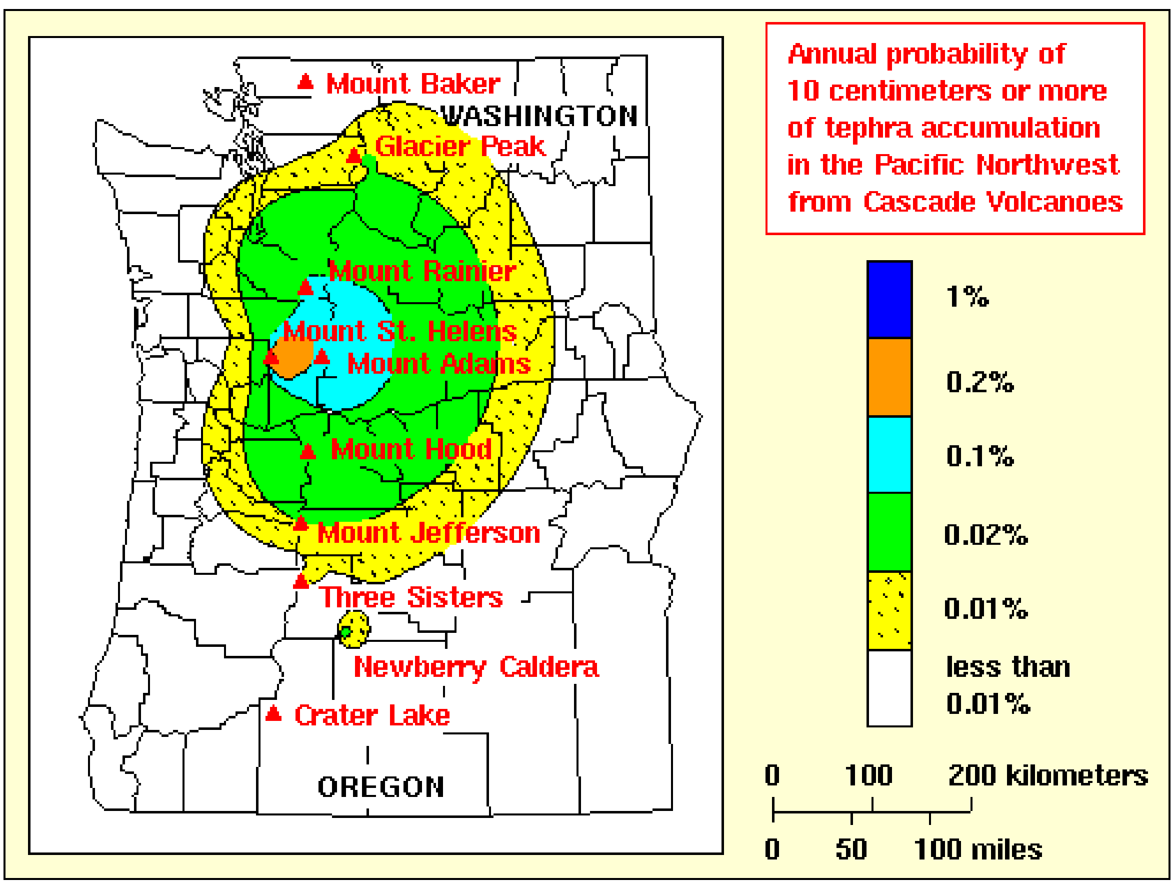


Figure 14-4. Annual Probability of Tephra Fall in the Northwest

14.3.4 Severity

A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse. Ash is harsh, acidic and gritty, and it has a sulfuric odor. Ash may also carry a high static charge for up to two days after being ejected from a volcano. As ash combines with rain, sulfur dioxide in the ash combines with water to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat.

Lahars are mixtures of water, rock, sand, and mud that rush down valleys leading away from a volcano. They can travel over 50 miles downstream, commonly reaching speeds between 20 and 40 miles per hour. Sometimes they contain so much rock debris (60 to 90 percent by weight) that they look like fast-moving rivers of wet concrete. Close to the volcano they have the strength to rip huge boulders, trees, and houses from the ground and carry them down-valley. Further downstream they simply entomb everything in mud. Historically, lahars have been one of the most deadly volcanic hazards.

The major hazard to human life from debris flows is from burial or impact by boulders and other debris. People and animals also can be severely burned by debris flows carrying hot debris. Buildings and other property in the path of a debris flow can be buried, smashed, or carried away. Because of their relatively high density and viscosity, debris flows can move and even carry away vehicles and other objects as large as bridges and locomotives.

Because debris flows are confined to areas downslope and down-valley from their points of origin, people can avoid them by seeking high ground. People seeking to escape flows should climb valley sides rather than try to outrun debris flows in valley bottoms. Debris-flow hazard decreases gradually down-valley from volcanoes but more abruptly with increasing altitude above valley floors. During eruptive activity or precursors to eruptions, local government officials evacuate areas likely to be affected.

14.3.5 Warning Time

Constant monitoring of all active volcanoes means that there will be more than adequate time for evacuation before an event, and adequate time to find shelter or protect property after an event. Since 1980, Mount St. Helens has settled into a pattern of intermittent, moderate and generally non-explosive activity, and the severity of tephra, explosions and lava flows have diminished. All episodes, except for one very small event in 1984, have been successfully predicted several days to three weeks in advance. However, scientists remain uncertain as to whether the current cycle of explosive activity ended with the 1980 explosion. The possibility of further large-scale events continues for the foreseeable future.

14.4 SECONDARY HAZARDS

Secondary hazards associated with volcanic eruptions are mud flows and landslides as well as traffic disruptions. The mudflow and landslide hazards are not typical for King County, but there could be traffic disruption caused by accumulation of ash fall. It should also be noted that past volcanic activity in the Cascade ranges has been preceded by an earthquake.

14.5 CLIMATE CHANGE IMPACTS

Large-scale volcanic eruptions can reduce the amount of solar radiation reaching the Earth’s surface, lowering temperatures in the lower atmosphere and changing atmospheric circulation patterns. The massive outpouring of gases and ash can influence climate patterns for years. Sulfuric gases convert to sub-micron droplets containing about 75 percent sulfuric acid. These particles can linger three to four years in the stratosphere. Volcanic clouds absorb terrestrial radiation and scatter a significant amount of incoming solar radiation, an effect that can last from two to three years following a volcanic eruption.

14.6 EXPOSURE AND VULNERABILITY

All of the King County planning area would be exposed to tephra from volcanic eruptions in the Cascade Range to some degree. The location of the event as well as the prevailing wind direction would influence the extent of this impact. Only the southern portion of the county along the White River is considered to be exposed to lahar flows from Mt. Rainier.

14.6.1 Population

The entire population of King County is exposed to the effects of a tephra fall. The populations most vulnerable to the effects of a tephra fall are the elderly, the very young and those already experiencing ear, nose and throat problems. People who lack adequate shelter are also vulnerable to tephra fall.

Population centers in the lahar path along the White River could become isolated after a volcanic eruption, although there would likely be adequate warning time for these cities to evacuate. Population could not be examined by lahar zone because census block group areas do not coincide with the lahar risk areas. However, population was estimated using the structure count of buildings within the lahar zones and applying the census value for persons per household for King County (2.39). Using this approach, it is estimated that the population living in the lahar zone is 10,900. This approach could understate the exposure by as much as a factor of two, so it is reasonable to assume that the exposed population is between 10,000 and 20,000, less than 5 percent of the total county population.

14.6.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for exposure and vulnerability of general property to the volcano hazard.

14.6.3 Critical Facilities and Infrastructure

The impacts of tephra on district facilities is considered to be negligible, so no exposure or vulnerability analysis was performed. The exposure and vulnerability analyses for the lahar hazard focused on indentifying facilities in mapped lahar zones in the White River basin. All district facilities along the White River are exposed to the lahar hazard. Table 14-2 lists those facilities. In all, it is estimated that 7.28 miles of levees and revetments are in areas susceptible to lahar. The estimated replacement cost for these facilities exceeds $76.8 million.

**TABLE 14-2.
LAHAR EXPOSURE-KING COUNTY LEVEES AND REVETMENTS**

River Basin	Facility Type	Linear Feet Exposed	Replacement cost[a]
White	Levee	9,475	$18,950,000
	Revetment	28,938	$57,876,000
Total		**38,413**	**$76,826,000**

a. Replacement cost determined using $2,000/lineal foot based upon county data from past projects

14.6.4 Environment

The environment is highly exposed to the effects of a volcanic eruption. Even if ash fall from a volcanic eruption were to fall elsewhere, it could still be spread throughout the county by surrounding rivers and streams. A volcanic blast would expose the local environment to effects such as lower air quality and other elements that could harm local vegetation and water quality.

Lahars racing down river valleys and spreading across floodplains tens of miles downstream from a volcano often cause serious economic and environmental damage. A lahar's turbulent flow front and the boulders and logs carried by the lahar can easily crush, abrade, or shear off at ground level just about anything in the path of the lahar. Even if not crushed or carried away by the force of a lahar, buildings and valuable land may become partially or completely buried by one or more cement-like layers of rock debris. By destroying bridges and key roads, lahars can trap people in areas vulnerable to other hazardous volcanic activity, especially if the lahars leave deposits that are too deep, too soft, or too hot to cross. Lahars can destroy by direct impact, lead to increased deposition of sediment, block tributary streams and bury valleys and communities with debris.

14.7 FUTURE TRENDS IN DEVELOPMENT

King County's population increased by approximately 9 percent between 2000 and 2009, and has averaged 1.19 percent annual growth since 1990. It is anticipated that King County will continue to grow at similar rates in the near future. As a special purpose district with a principle mission to manage flood risk, King County Flood Control District has a limited role in mitigating increased volcano risk associated with future development. The district's focus for volcano risk mitigation will be to manage the specific facilities for which it has responsibility. As facilities along the White River are upgraded or replaced, the district will have the opportunity to incorporate volcano risk reduction into the design of the improvements.

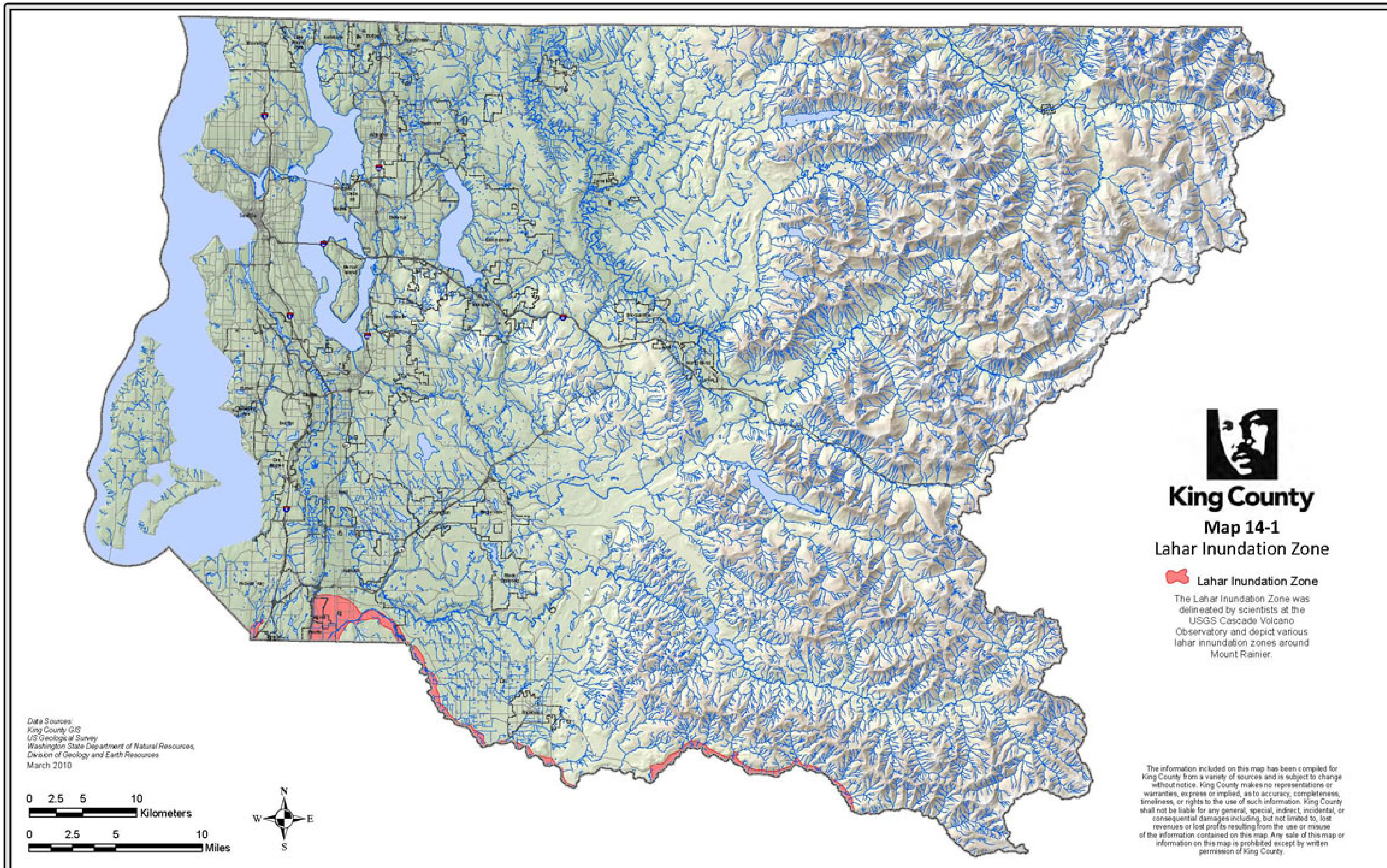
District funds are based on a countywide levy tax. As the population increases and additional homes are built to house the increased population, the district's revenue increases to reflect new construction and a maximum annual increase of 1 percent, under the provisions of Initiative 747. While this could increase total revenues over time, it is unlikely to keep pace with inflation over the long term.

14.8 SCENARIO

The worst case scenario for the King County Flood Control District would be a massive eruption from Mt. Rainier. The lahar flow along the White River in conjunction with this eruption could have devastating impacts on district facilities in the White River basin, similar to those seen along the Toutle River following the Mt. St. Helens eruption in 1980. King County resources would be taxed during such an event with widespread damage in the south portion of the county. There would probably not be any loss of life, due to adequate warnings.

14.9 ISSUES

Since volcanic episodes have been fairly predictable in the recent past, there is not as much concern about loss of life, but there is concern with loss of property, infrastructure and severe environmental impacts.


King County
Map 14-1
Lahar Inundation Zone
Lahar Inundation Zone
The Lahar Inundation Zone was delineated by scientists at the USGS Cascade Volcano Observatory and depict various lahar innundation zones around Mount Rainier.
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources, Division of Geology and Earth Resources
March 2010
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CHAPTER 15.
WILDLAND FIRE

15.1 WILDLAND FIRE DEFINED

The following definitions apply in the discussion of wildland fire hazards:

- **Conflagration**—A conflagration is a fire that grows beyond its original source area to engulf adjoining regions. Wind, extremely dry or hazardous weather conditions, excessive fuel buildup and explosions are usually the elements behind a wildfire conflagration.
- **Firestorm**—A firestorm is a fire that expands to cover a large area, often more than a square mile. A firestorm usually occurs when many individual fires grow together to make one huge conflagration. The involved area becomes so hot that all combustible materials ignite, even if they are not exposed to direct flame. Temperatures may exceed 1000° Celsius as the fire creates its own local weather: superheated air and hot gases of combustion rise upward over the fire zone, drawing surface winds in from all sides, often at velocities approaching 50 miles per hour. Although firestorms seldom spread because of the inward direction of the winds, once started there is no known way of stopping them. Within the area of the fire, lethal concentrations of carbon monoxide are present; combined with the intense heat, this poses a serious life threat to responding fire forces. In exceptionally large events, the rising column of heated air and combustion gases carries enough soot and particulate matter into the upper atmosphere to cause cloud nucleation, creating a locally intense thunderstorm and the hazard of lightning strikes.
- **Interface Area**—An interface area is an area susceptible to wildland fires and where wildland vegetation and urban or suburban development occur together. An example would be the smaller urban areas and dispersed rural housing in forested areas.
- **Wildland Fire**—Wildland fires are fires caused by nature or humans that result in the uncontrolled destruction of forests, brush, field crops, grasslands, and real and personal property in non-urban areas. Because of their distance from firefighting resources and manpower, these fires can be difficult to contain and can cause a great deal of destruction.

15.2 GENERAL BACKGROUND

15.2.1 Wildland Fire Characteristics

The wildland fire season in Washington usually begins in early July and ends in late September with a moisture event; however, wildland fires have occurred in every month of the year. Drought, snow pack, and local weather conditions can expand the length of the fire season.

People start most wildland fires; major causes include arson, recreational fires that get out of control, smoker’s carelessness, debris burning, and children playing with fire. From 1992 to 2001, on average, people caused more than 500 wildland fires each year on state-owned or protected lands; this compares to 135 fires caused by lightning strikes. Wildland fires started by lightning burn more state-protected acreage than any other cause, an average of 10,866 acres annually; human caused fires burn an average of 4,404 state-protected acres each year. Fires during the early and late shoulders of the fire season usually are associated with human-caused fires; fires during the peak period of July, August and early September often are related to thunderstorms and lightning strikes.

How a fire behaves primarily depends on the following:

- Fuel—Lighter fuels such as grasses, leaves and needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs and trunks take longer to warm and ignite. Snags and hazard trees—those that are diseased, dying, or dead—are larger but less prolific west of the Cascades than east of the Cascades. In 2002, about 1.8 million acres of the state's 21 million acres of forestland contained trees killed or defoliated by forest insects and diseases.
- Weather—West of the Cascades, strong, dry east winds in late summer and early fall produce extreme fire conditions. East wind events can persist up to 48 hours, with wind speed reaching 60 miles per hour; these winds generally reach peak velocities during the night and early morning hours.
- Thunderstorm activity—The thunderstorm season typically begins in June with wet storms, and turns dry with little or no precipitation reaching the ground as the season progresses into July and August.
- Terrain—The topography of a region influences the amount and moisture of fuel; the impact of weather conditions such as temperature and wind; potential barriers to fire spread, such as highways and lakes; and elevation and slope of land forms (fire spreads more easily uphill than downhill).
- Time of Day—A fire's peak burning period generally is between 1 p.m. and 6 p.m.

Short-term loss caused by a wildland fire can include the destruction of timber, wildlife habitat, scenic vistas, and watersheds. Vulnerability to flooding increases due to the destruction of watersheds. Long-term effects include smaller timber harvests, reduced access to affected recreational areas, and destruction of cultural and economic resources and community infrastructure.

15.3 HAZARD PROFILE

15.3.1 Past Events

The largest fire in King County history remains the 1889 Seattle fire, which was estimated to have consumed 60 acres of the downtown area. Also notable was the Blackstock lumberyard fire in 1989 which took the life of one fire fighter and the Mary Pang warehouse fire in 1995 which killed four fire fighters. In contrast, wildland fires historically, were not considered a hazard, as fire is a normal part of most forest and range ecosystems in the temperate regions of the world, including King County. Fires historically burn on a fairly regular cycle, recycling carbon and nutrients stored in the ecosystem, and strongly affecting the species within the ecosystem. The burning cycle in western Washington is every 100 – 150 years. Controlled burns have also been conducted because the fire cycle is an important aspect of management for many ecosystems. These are not considered hazards unless they were to get out of control. None of Washington State's most significant wildland fires have occurred in King County, although smaller wildland fires have occurred in the region. All but the Snoqualmie Pass area of King County is part of the South Puget Sound fire protection region of the Washington Department of Natural Resources. From 1992 to 2001, the South Puget Sound region averaged 182 fires a year that burned an average of 81 acres of state-protected lands.

15.3.2 Location

Map 15-1 shows wildland urban interface areas, or WUIAs, for King County as defined by the Washington Department of Natural Resources (September 2004). This map is based on data from the current National Fire Protection Association risk assessment (NFPA 299).

These areas tend to be in the foothills and valleys east of Puget Sound stretching into the lower reaches of the Cascades, where people are present in semi-urban densities. Wildfire analysis has been done using WUIA data created by the Department of Natural Resources, which analyzed areas with population densities of at least 20 people per square mile, defensible space, access and ingress, water capabilities, fuel supply, weather and topography and speed of response.

15.3.3 Frequency

A frequency estimate based on the annual average number of recorded fires in the Mount Baker-Snoqualmie National Forest may be statistically significant for King County. Although the Mount Baker-Snoqualmie Forest encompasses parts of Whatcom, Skagit, Snohomish, King and Pierce Counties, and therefore the number of fires is not necessarily a specific indicator of King County's risk, the fact that the forest environment is essentially uniform should provide for a reliable first guess. For the fire years 1995-2004, the annual number of fires in the Mount Baker-Snoqualmie National Forest ranged from 11 to 78, with an average of 31.

15.3.4 Severity

Potential losses from wildfire include human life, structures, and other improvements, and natural resources. There are no recorded incidents of loss of life from wildfires in King County, and the risk from wildfire has been deemed moderate by the state. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal. Smoke and air pollution from wildfires can be a severe health hazard, especially for sensitive populations including children, the elderly and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. In addition, wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds.

15.3.5 Warning Time

Wildfires are typically caused by humans, whether intentionally or accidentally. There is no way to predict when one might break out. Since it is reported that fireworks often cause brush fires, extra diligence might need to be taken around the Fourth of July when the use of fireworks is highest. Dry lightning may also trigger wildfires. Severe weather can be predicted, so special attention can be paid during weather events that may trigger wildfires. If a fire does break out and spread rapidly, residents may need to evacuate within days or hours. Reliable National Weather Service lightning warnings are available on average 24 to 48 hours prior to a significant electrical storm. Dry seasons and droughts are factors that greatly increase fire likelihood. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

15.4 SECONDARY HAZARDS

Wildland fires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable timber and indirect economic losses in reduced tourism. Wildland fires cause the contamination of reservoirs, destroy transmission lines and contribute to flooding. Wildfires strip slopes of vegetation, exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire. Most wildland fires burn hot and for long durations that can bake soils, especially those high in clay content, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events, thus increasing the chance of flooding.

15.5 CLIMATE CHANGE IMPACTS

Fire in western ecosystems is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildland fire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildland fire danger by warming and drying out vegetation, when climate alters fuel loads and fuel moisture, forest susceptibility to wildland fires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

Historically, drought patterns in the West are related to large-scale climate patterns in the Pacific and Atlantic oceans. The El Niño–Southern Oscillation in the Pacific varies on a 5- to 7-year cycle, the Pacific Decadal Oscillation varies on a 20- to 30-year cycle, and the Atlantic Multidecadal Oscillation varies on a 65- to 80-year cycle. As these large-scale ocean climate patterns vary in relation to each other, drought conditions shift from region to region in the United States. El Niño years bring drier conditions to the Pacific Northwest and more fires.

Climate scenarios project summer temperature increases between 2ºC and 5°C and precipitation decreases of up to 15 percent. Such conditions would exacerbate summer drought and further promote high-elevation wildland fires, releasing stores of carbon and further contributing to the buildup of greenhouse gases. Forest response to increased atmospheric carbon dioxide—the so-called “fertilization effect”—could also contribute to more tree growth and thus more fuel for fires, but the effects of carbon dioxide on mature forests are still largely unknown. High carbon dioxide levels should enhance tree recovery after fire and young forest regrowth, as long as sufficient nutrients and soil moisture are available, although the latter is in question for many parts of the western United States because of climate change.

15.6 EXPOSURE

15.6.1 Population

Population could not be examined by WUIA because census block group areas do not coincide with the fire risk areas. However, population was estimated using the structure count of buildings in the WUIA and applying the census value for persons per household for King County (2.39). Using this approach, it is estimated that the population living with the WUIA is 8,300. This approach could understate the exposure by as much as a factor of two, so it is reasonable to assume that the exposed population is between 8,000 and 16,000. This represents a very small percentage of the total county population.

15.6.2 Property

The district has a role in mitigating hazards to general property only for the flooding hazard and the dam-failure hazard, which is directly related to flooding. Therefore, no analysis was performed for exposure of general property to the wildland fire hazard.

15.6.3 Critical Facilities and Infrastructure

None of the district’s critical facilities are exposed to the WUIA.

15.6.4 Environment

Wildfires can cause severe environmental impacts:

- Damaged Fisheries—Critical trout, salmon and steelhead fisheries in the Pacific Northwest can suffer from increased water temperatures, sedimentation, and changes in water quality.

- Soil Erosion—The protective covering provided by foliage and dead organic matter is removed, leaving the soil fully exposed to wind and water erosion. Accelerated soil erosion occurs, causing landslides and threatening aquatic habitats.
- Spread of Invasive Plant Species—Non-native woody plant species frequently invade burned areas. When weeds become established, they can dominate the plant cover over broad landscapes, and become difficult and costly to control.
- Disease and Insect Infestations—Unless diseased or insect-infested trees are swiftly removed, infestations and disease can spread to healthy forests and private lands. Timely active management actions are needed to remove diseased or infested trees.
- Destroyed Endangered Species Habitat—Catastrophic fires can have devastating consequences for endangered species. For instance, the Biscuit Fire in Oregon destroyed 125,000 to 150,000 acres of spotted owl habitat.
- Soil Sterilization—Topsoil exposed to extreme heat can become water repellant, and soil nutrients may be lost. It can take decades or even centuries for ecosystems to recover from a fire. Some fires burn so hot that they can sterilize the soil.

15.7 VULNERABILITY

Since no district facilities are directly exposed to wildland fire, no vulnerability analysis was performed. However, it should be noted that some of the secondary impacts of wildland fires, could have significant impacts on district facilities. Fires can denature hillsides and bake the ground to an impenetrable consistency, which can significantly increase runoff during storm events. These denatured hillsides are also prone to slides, which can obstruct or relocate stream channels.

15.8 FUTURE TRENDS IN DEVELOPMENT

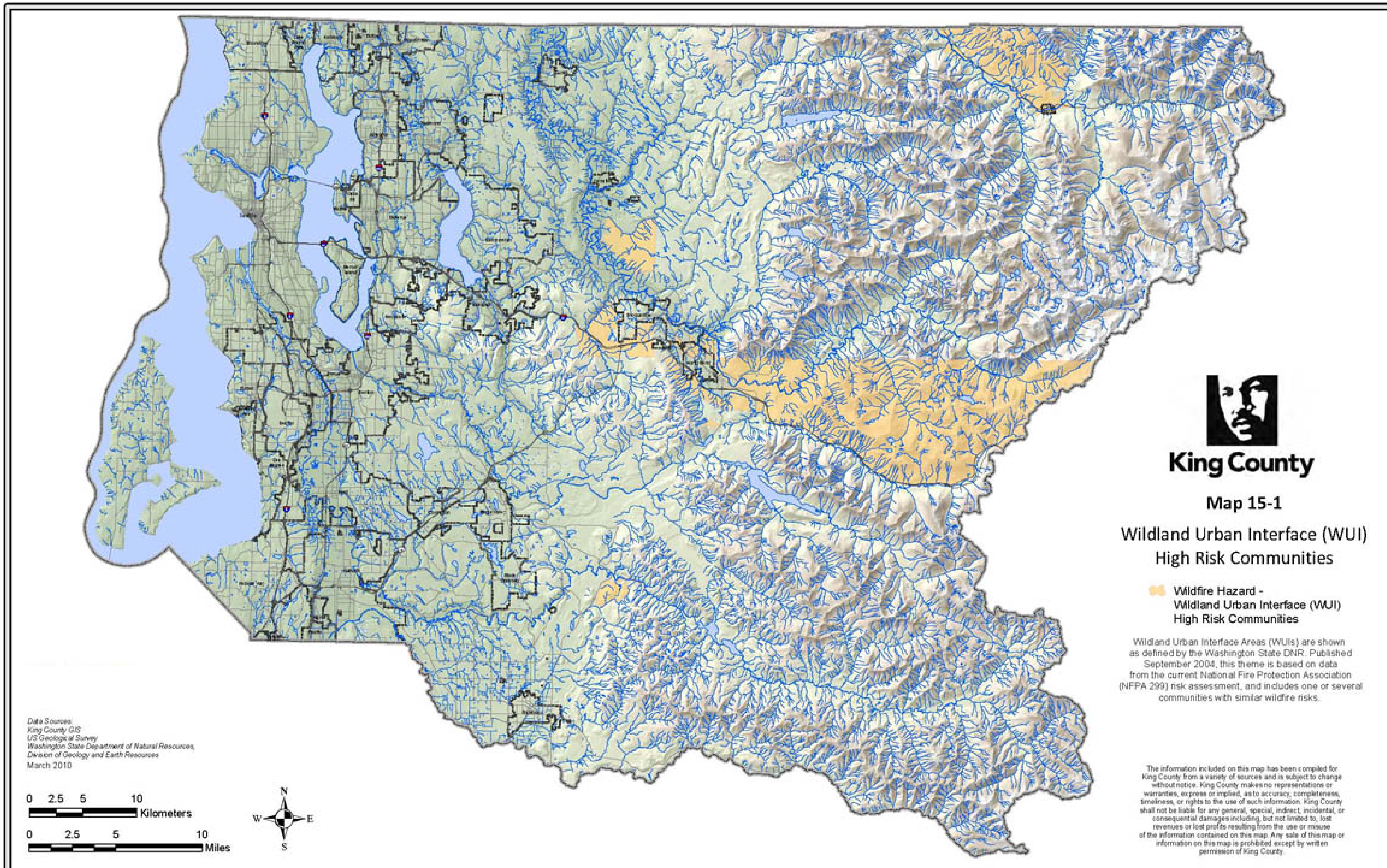
It is assumed that development trends in King County are not such that there is major concern about development in identified wildland fire hazard zones. The county is adequately equipped with an effective Comprehensive Plan to manage its growth so that expansion into hazard areas is discouraged by the county's land use policy. Since few, if any, of the district's facilities are directly exposed to the wildland fire hazard, future development is not considered to have any impact on the district's facilities.

15.9 SCENARIO

There are no wildland fire scenarios that would directly impact the King County Flood Control District's facilities. However, any major fire in King County could generate the secondary impacts on district facilities discussed earlier. Any such impacts would tax county resources, including those of the district, for event response and recovery.

15.10 ISSUES

There are currently no significant issues concerning the district in regards to the wildland fire hazard.



King County
Map 15-1
Wildland Urban Interface (WUI)
High Risk Communities
Wildfire Hazard -
Wildland Urban Interface (WUI)
High Risk Communities
Wildland Urban Interface Areas (WUIs) are shown as defined by the Washington State DNR. Published September 2004, this theme is based on data from the current National Fire Protection Association (NFPA 299) risk assessment, and includes one or several communities with similar wildfire risks.
Data Sources:
King County GIS
US Geological Survey
Washington State Department of Natural Resources,
Division of Geology and Earth Resources
March 2010
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CHAPTER 16.
PLANNING AREA RISK RANKING

A risk ranking was performed for the hazards of concern described in this plan. The risk ranking describes the probability of occurrence for each hazard and the impact each would have on people, property and the operations of the King County Flood Control District. Estimates of risk were generated with data from HAZUS-MH using methodologies promoted by FEMA.

16.1 PROBABILITY OF OCCURRENCE

The probability of occurrence of a hazard is indicated by a probability factor based on yearly likelihood of occurrence:

- High—Hazard event is likely to occur within 25 years (Probability Factor = 3)
- Medium—Hazard event is likely to occur within 100 years (Probability Factor =2)
- Low—Hazard event is not likely to occur within 100 years (Probability Factor =1)
- No exposure—there is no probability of occurrence (Probability Factor = 0)

The assessment of hazard frequency is generally based on past hazard events in the area. Table 16-1 summarizes the probability assessment for each hazard of concern for this plan.

TABLE 16-1.
PROBABILITY OF HAZARDS

Hazard Event	Probability (high, medium, low)	Probability Factor
Dam Failure	Medium	2
Earthquake	High	3
Flood	High	3
Landslide	High	3
Severe Weather	High	3
Volcano	Low	1
Wildland Fire	Low	1

16.2 IMPACT

Hazard impacts were assessed in three categories: impacts on people, impacts on property and impacts on district operations. Numerical impact factors were assigned as follows:

- **People**—Values were assigned based on the percentage of the total ***population exposed*** to the hazard event. The degree of impact on individuals will vary and is not measurable, so the calculation assumes for simplicity and consistency that all people exposed to a hazard because they live in a hazard zone will be equally impacted when a hazard event occurs. It should be noted that planners can use an element of subjectivity when assigning values for impacts on people. Impact factors were assigned as follows:

- High—50 percent or more of the population is exposed to a hazard (Impact Factor = 3)
- Medium—25 percent to 49 percent of the population is exposed to a hazard (Impact Factor = 2)
- Low—25 percent or less of the population is exposed to the hazard (Impact Factor = 1)
- No impact—None of the population is exposed to a hazard (Impact Factor = 0)

• **Property**—Values were assigned based on the percentage of the total ***value of district facilities exposed*** to the hazard event. For this exercise, value is considered as the full replacement cost of a district facility. Impact factors were assigned as follows:

- High—30 percent or more of the total replacement costs for all facilities is exposed to a hazard (Impact Factor = 3)
- Medium—15 percent to 29 percent of the total replacement costs for all facilities is exposed to a hazard (Impact Factor = 2)
- Low—14 percent or less of the total replacement costs of all facilities is exposed to the hazard (Impact Factor = 1)
- No impact—No facilities are exposed to a hazard (Impact Factor = 0)

• **Operations—** Values were assigned based on the ***time required to become 100-percent operational*** after a hazard event, also called the "functional downtime." For this exercise, estimates of functional downtime per facility type are averaged. Levees take longer to repair that revetments or pump stations. Impact factors were assigned as follows:

- High— functional downtime of 365 days or more. (Impact Factor = 3)
- Medium— Functional downtime of 180 to 364 days (Impact Factor = 2)
- Low— Functional downtime of 180 days or less (Impact Factor = 1)
- No impact—No functional downtime of facilities (Impact Factor = 0)

The impacts of each hazard category were assigned a weighting factor to reflect the significance of the impact. These weighting factors are consistent with those typically used for measuring the benefits of hazard mitigation actions: impact on people was given a weighting factor of 3; impact on property was given a weighting factor of 2; and impact on the operations was given a weighting factor of 1.

Tables 16-2, 16-3 and 16-4 summarize the impacts for each hazard.

16.3 RISK RATING AND RANKING

The risk rating for each hazard was determined by multiplying the probability factor by the sum of the weighted impact factors for people, property and operations, as summarized in Table 16-5.

Based on these ratings, a priority of high, medium or low was assigned to each hazard. The hazards ranked as being of highest concern to the district are flood, dam failure, and earthquake. Hazards ranked as being of medium concern for the district are severe weather and landslide. The hazards ranked as being of lowest concern are volcano and wildland fire. Table 16-6 shows the hazard risk ranking.

TABLE 16-2.
IMPACT ON PEOPLE FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (3)
Flooding	High[a]	3	9
Dam Failure	Medium	2	6
Earthquake	High	3	9
Landslide	Low	1	3
Severe Weather	Medium	2	6
Volcano	Low	1	3
Wildland Fire	Low	1	3

a. Although the statistical data warrant a Medium score for the flood hazard’s impact on people, a High score was assigned to recognize indirect impacts that floods have on populations who live outside the floodplain, such as impacts on those who work for businesses within the floodplain or must drive through the floodplain during flood events. These impacts are not measurable, yet can be significant.

TABLE 16-3.
IMPACT ON PROPERTY FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (2)
Flooding	High	3	6
Dam Failure	High	3	6
Earthquake	Medium	2	4
Landslide	Low	1	2
Severe Weather	Low	1	2
Volcano	Low	1	2
Wildland Fire	No Impact	0	0

TABLE 16.-4.
IMPACT ON DISTRICT OPERATIONS FROM HAZARDS

Hazard Event	Impact (high, medium, low)	Impact Factor	Multiplied by Weighting Factor (1)
Flooding	High	3	3
Dam Failure	High	3	3
Earthquake	Medium	2	2
Landslide	Low	1	1
Severe Weather	Low	1	1
Volcano	Low	1	1
Wildland Fire	No Impact	0	0

**TABLE 16-5.
HAZARD RISK RATING**

Hazard Event	Probability Factor	Sum of Weighted Impact Factors	Total (Probability x Impact)
Flood	3	9+6+2=17	51
Earthquake	3	9+4+2=15	45
Dam Failure	2	6+6+3=15	30
Severe Weather	3	6+2+1=9	27
Landslide	3	3+2+1=6	18
Volcano	1	3+2+1=6	6
Wildland Fire	1	3+0+0=3	3

**16-6.
HAZARD RISK RANKING**

Hazard Ranking	Hazard Event	Category
1	Flooding	High
2	Earthquake	High
3	Dam Failure	High
4	Severe Weather	Medium
5	Landslide	Medium
6	Volcano	Low
7	Wildland Fire	Low

PART 3—MITIGATION STRATEGY

CHAPTER 17.
MITIGATION INITIATIVES

17.1 INTRODUCTION

The *2006 King County Flood Hazard Management Plan* identifies and recommends a suite of projects, programs and policies to address flooding issues in King County. This plan was adopted by the King County Flood Control District as its comprehensive plan under RCW 86.15. Stated goals of the plan are to reduce risks from the flood and channel migration hazards; to avoid or minimize the environmental impacts of flood hazard management; and to reduce the long-term costs of flood hazard management. The proposed district work program consists of two major categories:

- Programmatic Work Program
  - Flood Preparedness, Regional Flood Warning Center, and Post Flood Recovery
  - Flood Hazard Assessments, Mapping, and Technical Studies
  - Planning, Grants, Mitigation, and Public Outreach
  - District Implementation
  - Resource Management, Annual Maintenance, and Facility Monitoring
  - Management, Finance, Budget and General Administration
- Capital Improvement Program
  - Capital Improvement Projects
  - Acquisitions and Elevations

This work plan supported by the district's budget is the action plan for this hazard mitigation plan. As a flood control district, the district will always target flood risk reduction as its highest priority. However, many of these actions address impacts from multiple hazards impacting district facilities.

17.2 CAPABILITY ASSESSMENT

The planning committee performed an inventory and analysis of the district's existing authorities and capabilities. The capability assessment creates an inventory of an agency's mission, programs and policies, and evaluates its capacity to carry them out. Table 17-1 summarizes the legal and regulatory capability of the King County Flood Control District. Table 17-2 summarizes the district's administrative and technical capability. Table 17-3 summarizes the district's fiscal capability.

17.3 BENEFIT/COST REVIEW

The DMA requires prioritization of the action plan according to a benefit/cost analysis of the proposed projects (44CFR Section 201.6(c)(3)(iii)). The planning committee adapted the district's existing project prioritization criteria into a benefit/cost methodology that meets the intent of the regulation.

**TABLE 17-1.
LEGAL AND REGULATORY CAPABILITY**

Regulatory Tools (Codes, Ordinances, Plans)	Local Authority	State or Federal Prohibitions	Other Jurisdictional Authority	State Mandated	Comments
1. Building Code	No	No	No	No	The district possesses no permit authority for the construction of buildings.
2. Zoning Ordinance	No	No	No	No	The district possesses no land use authority.
3. Subdivision Ordinance	No	No	No	No	The district has no regulatory authority over the sub-division of lands within King County.
4. Special Purpose Ordinances (floodplain management and critical or sensitive areas)	No	No	No	No	The district has no regulatory capacity, and therefore has no special purpose ordinances.
5. Growth Management	No	No	No	No	The district is not subject to the provisions of the Washington Growth Management Act.
6. Floodplain Management or Basin Plan	Yes	NA	No	No	2006 King County Flood Hazard Management Plan created the flood control district to implement the recommendations of the plan. Scheduled for an update by 2011.
7. Stormwater Management Plan/ Ordinance	No	No	No	No	
8. General Plan or Comprehensive Plan	No	No	No	No	The 2006 Flood Hazard Management Plan is the district's comprehensive plan of development for flood control under RCW 86.15.110.
9. Capital Improvement Plan	Yes	NA	No	No	The district has a 6-year capital improvement plan for flood control projects that is reviewed and updated at least annually.

TABLE 17-1 (continued).
LEGAL AND REGULATORY CAPABILITY

Regulatory Tools (Codes, Ordinances, Plans)	Local Authority	State or Federal Prohibitions	Other Jurisdictional Authority	State Mandated	Comments
10. Site Plan Review Requirements	No	No	No	No	The district supports King County’s floodplain management program by providing technical review for all development in the unincorporated county floodplain.
11. Habitat Conservation Plan	No	NA	No	No	The district has prepared no plans approved as a habitat conservation plan by a state or federal agency.
12. Economic Development Plan	No	No	No	No	
13. Emergency Response Plan	Yes	NA	No	Yes	The district is responsible for the operation of the King County Flood Warning Center. The district maintains a flood warning handbook that is updated annually. This handbook dictates response to flood events within the county
14. Shoreline Management Plan	No	No	No	No	The district is not subject to the provisions of the Shoreline Management Act (RCW 90.58)
15. Post-Disaster Recovery Plan	No	NA	No	No	
16. Post-Disaster Recovery Ordinance	No	NA	No	No	
17. Hazard Mitigation Plan	Yes	No	No	No	The district created a local hazard mitigation plan in response to Public Law 106-390 in March 2010.

TABLE 17-2. ADMINISTRATIVE AND TECHNICAL CAPABILITY		
Staff/ Personnel Resources	Available ?	Department or Agency (Positions)
1. Planners or Public Information Staff with expertise in natural hazard management and planning	Yes	Through an agreement with King County, the district maintains programmatic personnel positions that include: • 7 Planners • 1 Public Information Officer; The district can also contract for public information services
2. Structural Engineers or professionals trained in construction practices.	Yes	
3. Engineers with expertise an understanding of natural hazards	Yes	The district maintains a pool of engineers assigned to each river basin in the county, totaling 14 staff positions. The district also can contract for engineering services
4. Certified Floodplain Managers	Yes	Three district staff members are certified floodplain managers
5. Surveyors	Yes	The district staffs no surveyor positions. However the district can and has contracted for this service on an as-needed basis.
6. Personnel skilled or trained in GIS Applications	Yes	District personnel include 1 position dedicated to GIS applications.
7. Scientist familiar with natural hazards in King County	Yes	District personnel include 5 scientist/biologist positions
8. Emergency manager	Yes	All personnel assigned to Flood Warning Center operations are trained as flood emergency managers
9. Grant writers	Yes	The district has completed numerous grants internally as well as contracting for this service.
10. Staff with expertise or training in benefit/cost analysis	Yes	The district can and has contracted for this service
11. Staff with expertise in Risk Assessment methodologies such HEC/FDA or HAZUS	Yes	The district can and has contracted for this service

**TABLE 17-3.
FISCAL CAPABILITY**

Financial Resources	Accessible or Eligible to Use?
1. Community Development Block Grants	Yes
2. Capital Improvements Project Funding	Yes
3. Authority to Levy Taxes for Specific Purposes	Yes
4. User Fees For Water, Sewer, Gas or Electric Service	No
5. Impact Fees for Buyers or Developers of New Development/Homes	No
6. Incur Debt through General Obligation Bonds	Yes
7. Incur Debt through Special Tax Bonds	Yes
8. Incur Debt through Private Activity Bonds	No
9. Could Withhold Public Expenditures in Hazard-Prone Areas	No
10. State-Sponsored Grant Programs	Yes
11. Other	Eligible for FEMA and Corps of Engineers public assistance, federal grants

17.3.1 Cost Criteria

Parameters were established for assigning subjective ratings (high, medium, and low) to the costs and benefits of these projects. Cost ratings were defined as follows:

- **High**—Project cost greater than $5 million
- **Medium**—Project cost of $1 million to $5 million
- **Low**—Project cost of less than $1 million

17.3.2 Benefit Criteria

The following prioritization scheme for district projects is based on the *2006 King County Flood Hazard Management Plan* policies related to flood risk hierarchy (Policy G-2) and project prioritization (Policy PROJ-1). A risk factor is calculated for each project using the following criteria:

- ***What is the current land use?—***This criterion is intended to give different weights to different types of land uses. If more than one type of land use is at risk, select the applicable land use with the highest score. Use the score range provided to give more or less weight bases on site-specific conditions. For example, a sole access road would be given a higher score than one for which a reasonable alternative route exists. A value for this category is assigned between 1 and 12.

- ***How serious is the potential impact?***—This criterion is intended to evaluate the nature and severity of the impacts irrespective of the scale at which the impact will occur. The scoring range can be used to differentiate between similar types of impact that have different likelihoods of occurring. A value for this category is assigned between 1 and 12.
- ***How extensive will the impact be?***—This criterion describes the scale of the problem. Is the problem manifest over a large area or in a manner that will affect a large number of people, or is it more local? If the physical impact is over a small area but a larger number of people will be affected, apply a score based on the impact rather than just the physical area. The scoring range can be used to differentiate between different degrees of extensiveness within the listed categories. A value for this category is assigned between 1 and 8.
- ***How soon will the impact occur?***—This criterion is used to describe how soon the risk needs to be addressed to avoid its occurrence or reoccurrence. A value for this category is assigned between 1 and 6.

Current land use and seriousness of impact were given greater weight due to the fundamental objective of reducing risk to health, safety, and welfare. Combined, the four criteria allow for a maximum total rating of 38 points. Risk factor is calculated as a project's total score as a percentage of the total possible points (for example, a project scoring 33 of the possible 38 points for the four criteria has a risk factor of 87 percent). Benefit ratings were defined as follows:

- **High—** Risk factor score of 67 percent of the maximum possible score or higher
- **Medium—** Risk factor score of 33 to 66 percent of the maximum possible score
- **Low—** Risk factor score of 32 percent of the maximum possible score or lower

17.3.3 Benefit/Cost Ratio

Using this approach, projects with positive benefit versus cost ratios, such as high over high, high over medium or medium over low, are considered cost-beneficial and are prioritized accordingly. This benefit/cost analysis is not of the detail required for project grant eligibility under FEMA's Hazard Mitigation Grant Program or Pre-Disaster Mitigation grant program. A less formal approach was used because some projects may not be implemented for up to 10 years, and associated costs and benefits could change dramatically in that time frame.

For many of the strategies identified in this action plan, the district may seek FEMA grant funding. If so, the required detailed benefit/cost analyses will be performed at the time of application. The district is committed to implementing a mitigation strategy with benefits that exceeds costs. For projects not seeking financial assistance from grant programs that require detailed analysis, the district reserves the right to define benefits according to parameters that meet the goals and objectives of this plan.

17.4 PRIORITIZATION

The planning committee developed a prioritization methodology for the action plan that meets the needs of the district and the requirements of 44CFR (Section 201.6). The mitigation strategies were prioritized according to the following criteria:

- **High Priority—**A project that meets multiple plan objectives, has benefits that exceed cost, has funding secured under existing programs or authorizations or is grant-eligible, and can be completed in 1 to 5 years once project is funded (short-term project)
- **Medium Priority—**A project that meets at least one plan objective, has benefits that exceed cost, and can be completed in 1 to 5 years once project is funded, but for which funding has

not been secured and would require a special funding authorization under existing programs, and grant funding is not secured

- **Low Priority—**A project that will mitigate the risk of a hazard and has benefits that exceed cost, but for which funding has not been secured, and the project is not grant-eligible or the timeline for completion is long-term (5 to 10 years).

These priority definitions are dynamic and can change from one category to another based on changes to a parameter such as availability of funding. For example, a project might be assigned a medium priority because of the uncertainty of a funding source, but the priority could be changed to high once a funding source has been identified. The prioritization schedule for this plan will be reviewed and updated as needed annually through the plan maintenance strategy described in Chapter 7.

17.5 MITIGATION STRATEGY MATRICES

Tables 17-4 and 17-5 outline the hazard mitigation action plan identified by the planning committee and steering committee. The King County Flood Control District will be the lead agency for implementation of all initiatives. Table 17-4 identifies the following:

- River basin in which the action will occur
- Initiative number and summary description of the initiative
- Risk factor score
- Whether the initiative applies to new or existing assets
- Hazards mitigated by the initiative (FL = flood; DF = dam failure; EQ = earthquake; LS = landslide; SW = severe weather; VO = volcano)
- Objectives met by the initiative
- Estimated cost (if available)
- Possible sources of funding (FCAAP = Flood Control Assistance Account Program; CFT = Conservation Futures Trust; SRFB = Salmon Recovery Fund Board; KCD = King Conservation District)
- Timeline for completion
  - **Ongoing:** Currently being implemented under existing programs and budgets
  - **Short-term:** Can be completed within 1 to 5 years once funding has been secured
  - **Long-term:** Will take 5 or more years to complete once funding has been secured

Table 17-5 prioritizes the initiatives according to the parameters discussed in Sections 17.3 and 17.4. The priority matrix illustrates the following:

- Number of objectives met by the initiative
- Benefits of the project (high, medium, or low)
- Cost of the project (high, medium, or low)
- Do the benefits equal or exceed the costs?
- Is the project grant-eligible?
- Can the project be funded under existing programs and budgets?
- Priority (high, medium, or low).

TABLE 17-4.
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
South Fork Skykomish River Basin							
FL0001: Miller River Home Buyout—Acquire properties and remove monastery structures from flood and erosion hazard areas near mouth of Miller River.							
74%	Existing	FL	5, 6, 9, 10, 11	$805,215	Low	District capital funding, FEMA hazard mitigation grant, FCAAP, CFT	Short-term
FL0004: Timber Lane Village Home Buyouts—Acquire properties and remove homes and other structures from these flood hazard areas.							
76%	Existing	FL	5, 6, 9, 10, 11	$4,562,504	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL0005: South Fork Skykomish River Repetitive Loss Mitigation—Acquire, relocate or elevate identified repetitive loss structures, or structures exposed to repetitive flooding, to eliminate the associated risk of flood damage.							
74%	Existing	FL, EQ	5, 6, 9, 10, 11	$324,271	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL0010: South Fork Skykomish/Maloney Creek Confluence Improvements—Alter Maloney Creek channel and realign two levees in Town of Skykomish near Maloney creek confluence to improve flood protection for the town's school and several residences.							
63%	Both	FL	1, 2, 6, 10, 11	$50,000	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
Upper Snoqualmie River Basin							
FL1002: North Bend Area Residential Flood Mitigation—Acquire or elevate structures in the North Bend area to eliminate the risk of flooding or channel migration.							
89%	Existing	FL, EQ	5, 6, 9, 10, 11	$500,000	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL1003: South Fork Levee System Improvements—Rebuild and strengthen selected portions of the existing levee system in an approach that maintains current preferential protection of the more heavily developed parts of the City of North Bend.							
79%	Existing	FL, EQ	1, 2, 6, 10, 11	$5,922,215	High	District capital funding,	Short term
FL1017: Kimball Creek and Snoqualmie Basin—Evaluate re-channeling of sections of Kimball Creek to address sedimentation and related flooding issues from Kimball Creek and main stem S. Fork Snoqualmie River.							
68%	New and Existing	FL	1, 3, 6	$263,207	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL1019: Middle Fork Levee System Capacity Improvements—Realign or setback the existing levees to improve the conveyance capacity along the river channel.							
76%	Existing	FL, EQ	1, 2, 6, 10, 11	$3,715,404	Medium	District capital funding	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Upper Snoqualmie River Basin (continued)							
FL1022: SR-202 Bridge Lengthening on South Fork Snoqualmie River—Evaluate options and feasibility of altering SR-202 bridge across S. Fork Snoqualmie R., to avoid backwater effect and related overtopping of upstream levees and subsequent flooding.							
76%	Existing	FL, EQ	1, 3, 6, 8	$954,571	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL1023: Upper Snoqualmie Residential Flood Mitigation—Acquire, relocate, or elevate structures in the Upper Snoqualmie basin (above Snoqualmie Falls) to eliminate the risk of flooding or channel migration.							
89%	Existing	FL, EQ	5, 6, 9, 10, 11	$7,715,063	High	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
Lower Snoqualmie River Basin							
FL2001: Aldair and Fall City Reach Flood Mitigation—Acquire or relocate structures which are at risk from flooding or erosion along the main stem Snoqualmie River between Fall City and the confluence with Patterson Creek. Evaluate and implement levee setbacks to improve conveyance capacity in this reach.							
84%	Existing	FL, EQ	5, 6, 9, 10, 11	$3,973,781	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP, CFT, SRFB	Short-term
FL2002: Lower Snoqualmie River Flood Damage Repairs—Repair levees and revetments in the Lower Snoqualmie R. basin which are damaged during flood events; examples include the Sinnera Qualle Upper revetment and the Aldair levee which were damaged during the January 2009 flood.							
82%	Existing	FL	1, 2, 6, 10, 11	$700,000	Low	District capital funding	Short-term
FL2010: Farm/Flood Task Force Implementation—Provide technical and financial assistance to farmers in the Lower Snoqualmie Valley to address flooding and erosion problems; assistance can include barn elevations, farm pad construction, and other flood-related mitigation.							
N/A	New and Existing	All Hazards	3, 6, 7, 12	$642,626	Low	District capital funding	Short-term
FL2012: McElhoe/Person Levee—Remove or setback the McElhoe/Pearson levee along the main stem Snoqualmie River near Carnation, reconnect floodplain habitat, reduce need for long term maintenance of the facility, and reduce potential flooding and sediment problems.							
68%	New and Existing	FL, EQ	1, 2, 6, 10, 11	$1,420,045	Medium	District capital funding, CFT, SRFB, KCD	Short-term
FL2013: Tolt Pipeline Protection— Install one or more engineered log jams to roughen the river channel near the toe of the eroding bank, thereby helping to reduce local water velocities and the resulting toe erosion process.							
84%	Existing	FL, EQ, LS, DF	1, 2, 6, 10, 11	$3,031,989	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Lower Snoqualmie River Basin (continued)							
FL2014: Lower Snoqualmie River Repetitive Loss Mitigation—Acquire, relocate or elevate identified repetitive loss structures, or structures exposed to repetitive flooding, to eliminate the associated risk of flood damage.							
74%	Existing	FL, EQ, DF	5, 6, 9, 10, 11	$535,856	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL2015: McElhoe-Pearson Repair—Repair damages to the McElhoe-Pearson levee on the main stem Snoqualmie River which occurred during the January 2009 flood.							
79%	Existing	FL, DF	1, 2, 6, 10, 11	$50,000	Low	District capital funding	Short-term
FL2019: Schiessel-Phiffer Repair—Repair damages to the Schiessel-Phiffer revetment on the main stem Snoqualmie River which occurred during the January 2009 flood.							
76%	Existing	FL, DF	1, 2, 6, 10, 11	$600,000	Low	District capital funding	Short-term
FL2020: Lower Snoqualmie Residential Flood Mitigation—Acquire, relocate or elevate residential and agricultural structures in the Lower Snoqualmie to reduce risks and damages associated with flooding and erosion.							
89%	Existing	FL, EQ, DF	5, 6, 9, 10, 11	$300,000	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
Tolt River Basin							
FL3004: Lower Tolt River Acquisition—Acquire homes that are at risk from flood and channel migration hazards and reconfigure Edenholm levee to improve flood conveyance on Tolt River.							
74%	Existing	FL, EQ, DF	5, 6, 9, 10, 11	$1,017,850	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP, CFT	Short-term
FL3005: San Souci Neighborhood Buyout—Remove all homes from this hazardous area followed by removal of an existing, privately-assembled rubble levee at upstream end of community access road.							
82%	Existing	FL, DF	5, 6, 9, 10, 11	$2,629,405	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP, CFT, SRFB	Short-term
FL3007: Tolt River SR-203 to Trail Bridge Floodplain Reconnection—Setback existing levee on right bank to improve flood conveyance and reconnect floodplain habitat.							
61%	New and existing	FL, EQ, DF	1, 2, 6, 10, 11	$2,331,672	Medium	District capital funding	Short-term
FL3008: Tolt River Repetitive Loss Mitigation—Acquire, relocate or elevate identified repetitive loss structures, or structures exposed to repetitive flooding, to eliminate the associated risk of flood damage.							
74%	Existing	FL, EQ, DF	5, 6, 9, 10, 11	$187,011	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Tolt River Basin (continued)							
FL3009: Tolt River Mile 1.1 Levee Setback—Setback the levee on the left bank of the Tolt River in the vicinity of the KC Parks trail bridge. Acquire homes downstream of the trail bridge so that the levee can be setback to improve flood conveyance, reconnect floodplain habitat, decrease long term maintenance costs, and decrease flood risks to development on both sides of the river.							
79%	Existing	FL, EQ, DF	1, 2, 6, 10, 11	$8,999,827	High	District capital funding	Short-term
Raging River Basin							
FL4001: Alpine Manor Mobile Home Park Neighborhood Buyout—The proposed project would include the acquisition and removal of most, if not all, of the homes in the neighborhood, and restoration of this riparian area in a manner that supports salmon habitat recovery needs. The project could be phased though a long-term acquisition and restoration strategy.							
74%	Existing	FL	5, 6, 9, 10, 11	$8,173,145	High	District capital funding, FEMA hazard mitigation grant, FCAAP, CFT	Short-term
FL4016: Abandoned Bridge Abutment and Waring Revetment Channel Constriction—Remove the remains of abandoned private bridge abutments on both banks of Raging River in vicinity of Alpine Manor Mobile Home Park. The abutments are constricting the river channel at this site; the project is to be done in conjunction with the Alpine Manor buyout project.							
68%	Existing	FL	2, 6, 10	$147,342	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL4021: Preston-Fall City Upper Repair—Repair the Preston-Fall City Upper revetment on the Raging River which was damaged during the January 2009 flood.							
66%	Existing	FL	1, 2, 6, 10, 11	$400,000	Low	District capital funding	Short-term
FL4022: Preston Fall City Lower Repair—Repair the Preston-Fall City Lower revetment on the Raging River which was damaged during the January 2009 flood.							
66%	Existing	FL	1, 2, 6, 10, 11	$250,000	Low	District capital funding	Short-term
Sammamish River Basin							
FL-5001-Willowmoor Floodplain Restoration-—Reconfigure the transition zone of the Sammamish River to increase channel complexity, establish a native plant community and riparian buffer, and maintain adequate flow conveyance to meet flood control obligations in a sustainable manner. This will involve widening the total cross-sectional area available for flood flows so that plants can be allowed to grow within the banks and not be an obstruction to that flow.							
58%	Existing	FL	1, 2, 6, 10, 11	$4,093,778	Medium	District capital funding	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Issaquah Creek Basin							
FL6001 – Issaquah Streambank Protection Project—Construct bank stabilization project to protect public infrastructure and health and safety.							
82%	Existing	FL	1, 2, 6, 10	$88,865	Low	District capital funding	Short-term
FL6002: Issaquah Creek Repetitive Loss Mitigation—Acquire, relocate or elevate identified repetitive loss structures, or structures exposed to repetitive flooding, to eliminate the associated risk of flood damage.							
74%	Existing	FL	5, 6, 9, 10, 11	$687,062	Low	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
Cedar River Basin							
FL7004: Cedar River Repetitive Loss Mitigation—Acquire, relocate or elevate identified repetitive loss structures, or structures exposed to repetitive flooding, to eliminate the associated risk of flood damage.							
74%	Existing	FL, EQ, DF	5, 6, 9, 10, 11	$2,831,331	Medium	District capital funding, FEMA hazard mitigation grants, FCAAP for acquisitions	Short-term
FL7005: Elliott Bridge Levee Setback and Acquisition—Acquire homes in repetitive loss area to eliminate the immediate flood risks, and setback or remove the levees on both banks to restore floodplain functions and reduce future flood damages through the reach.							
79%	Existing	FL, EQ, LS, DF	1, 2, 5, 6, 9, 10, 11	$2,882,408	Medium	District capital funding, Conservation Futures Tax, FEMA hazard mitigation grants, FCAAP for acquisitions	Short-term
FL7006: Rainbow Bend Levee Setback and Floodplain Reconnection—Once acquisition of the flood-prone properties immediately behind the levee is complete, the levee can be set back or removed. The levee setback will allow flows to be redirected away from the opposite bank levee that protects SR-169 and the Cedar River Trail, and will provide greater accommodation of flood conveyance and natural riverine processes within the extensive floodplain currently cut off from the river. The project will extend along three quarters of a mile of the main stem Cedar River, starting at Cedar Grove Road Bridge and proceeding downstream.							
76%	Existing	FL, EQ, DF	1, 2, 6, 8, 10	$2,070,031	Medium	District capital funding	Short-term
FL7014: Dorre Don Meanders, Phase 1—Conduct an assessment of flood risks in two densely populated neighborhoods subject to severe and repeated flooding – Dorre Don and Byers Bend. The study will identify potential solutions to the flooding problems and evaluate their benefits and feasibility.							
79%	Existing	FL, DF	3, 6, 7	$242,209	Low	District capital funding	Short-term
FL 7015: Herzman Levee Setback and Floodplain Reconnection-—Remove approximately 350 linear feet of the levee and set back another 190 linear feet in a manner that will allow flows to be redirected away from the vulnerable opposite bank that protects a major transportation corridor and a regional trail system. The levee setback will also reconnect the river with its floodplain without increasing flood risks to the existing homes or Jones Road.							
76%	Existing	FL, EQ, DF	1, 2, 6, 8, 10	$1,268,085	Medium	District capital funding	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Cedar River Basin (continued)							
FL7016: Jan Road-Rutledge Johnson Levee Setbacks—Levees on both banks constrict the river and direct high velocity flows toward a major transportation corridor and a regional trail system. Setback the levees in open space areas to improve flood storage and conveyance while still protecting nearby homes and infrastructure.							
76%	Existing	FL, EQ, DF	1, 2, 6, 8, 10	$1,234,993	Medium	District capital funding	Short-term
FL7017: Maplewood Acquisition and Levee Setback Phase 1 Alternatives Evaluation—Conduct an assessment of flood risks in the densely populated neighborhood of Maplewood, which is subject to a landslide hazard that could block the river channel and make existing overbank flood risks much more severe. The Study will identify potential solutions to the flooding problems and evaluate their benefits and feasibility.							
84%	New and existing	FL, EQ, LS, DF	3, 6, 7	$136,226	Low	District capital funding	Short-term
FL-7018: Cedar River Gravel Removal—The proposed action includes three elements: periodic gravel removal, spawning channel replacement and upper watershed gravel supplementation.							
89%	New and Existing	FL, DF	2, 6, 11	$6,169,339	High	District capital funding	Short-term
FL-7020: Lower Jones Road Setback—The riverbanks should be set back along this entire length of river to provide more room for flood conveyance and to reduce the risks of ongoing flood damage. At its upstream end, the flood protection facility and about a 1,500-foot section of Jones Road will need to be relocated landward to accommodate a stable slope angle on the banks, improved conveyance in the channel, and a buffer separating the river and the road.							
79%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$972,802	Low	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisitions	Short-term
FL7021: Riverbend Mobile Home Park Acquisition and Levee Setback—Purchase all or the most vulnerable portions of a mobile home park located in the floodplain and channel migration area. The existing revetment would be setback to continue to protect remaining homes while reducing risks of future flood damage and improving conveyance through the reach.							
82%	New and existing	FL, EQ, DF	1, 2, 5, 6, 9, 10, 11	$507,588	Low	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisition	Short-term
FL7022: Maplewood Acquisition and Levee Setback Phase 2—Preliminary recommendations for the Maplewood neighborhood include acquiring homes currently subject to repeated flooding as well as those at greatest risk of flooding and access cut-off that could result from channel avulsion through the neighborhood. A setback levee could be constructed to protect areas of the neighborhood at lower risk. New recommendations resulting from the flood assessment for this area could replace or combine with these project elements.							
84%	New and existing	FL, EQ, LS, DF	1, 2, 5, 6, 9, 10, 11	$960,660	Low	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisitions	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Cedar River Basin (continued)							
FL7023: Renton Cedar River Bridge Flood Reduction Project—Five bridges located within the City of Renton have low chord elevations at or below a 50-year flood elevation, and are vulnerable to overtopping and damage, as well as causing backwater effects upstream, as a result. When renovation or replacement is undertaken on these bridges, they should simultaneously be elevated above the base flood elevation. This project would construct the flood-related improvements of the overall bridge replacement projects.							
66%	New and existing	FL, EQ, DF	1, 2, 6, 8, 10	$694,091	Low	District capital funding	Short-term
FL7024: Bellevue Lower Coal Creek Phase 1—Increase storage capacity of a regional pond, replace five box culverts, and construct levee improvements where feasible to increase conveyance and reduce flooding of a densely populated area and the I-405 transportation corridor.							
71%	Existing	FL, DF	1, 2, 6, 10	$4,175,305	Medium	District capital funding	Short-term
FL7037: Rhode Levee Setback and Home Buyouts—Project designs for reducing flood damage and loss behind the Rhode Levee will need to give consideration to projects planned for the Getchman Levee on the opposite bank. The hydraulic model may need to be updated to reflect the new topographic conditions, and the results evaluated to determine the impact on flood hazards and future projects in the vicinity. Homes in the highest hazard areas should be acquired and the structures removed from the floodplain. Following acquisition of these flood-prone homes, and as part of a long-term flood hazard management strategy, channel conveyance should be expanded to safely accommodate flood flows while protecting Southeast 203rd Street and the remaining homes from any increased flood risk. This may be accomplished by setting back the levee or by constructing a conveyance channel through the floodplain.							
68%	New and Existing	FL, EQ, DF	1, 2, 5, 6, 9, 10, 11	$2,434,340	Medium	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisition	Short-term
FL7039: Dorre Don Phase 2—The primary recommendations for the Dorre Don neighborhood are to acquire homes in the floodway which are subject to fast and deep flood plows, and to setback the levees where possible to improve conveyance through the reach. New recommendations resulting from the flood assessment for this area could replace or combine with these project elements.							
79%	New and existing	FL, EQ, DF	1, 2, 5, 6, 9, 10, 11	$2,533,893	Medium	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisitions	Short-term
FL7040: Cedar Pre-Construction Strategic Acquisition—Acquire property interests necessary for implementation of projects in the district's 6-year capital improvement program.							
84%	Existing	FL, EQ, LS, DF	5, 6, 9, 10, 11	$9,216,775	High	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisitions	Short-term

**TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX**

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Green River Basin							
FL8016: Briscoe Levee #1-#3, #5-#8—Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of levee slopes at a minimum 2.5H:1V slope angle. The levee toe should be reconstructed with the installation of large woody debris structures, excavation of a mid-slope bench/buttress, and re-vegetation with live willow layers and native riparian trees and shrubs. The upper levee slopes should also be stabilized.							
92%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$19,675,253	High	District capital funding	Short-term
FL8017: Desimone Levee #1—Incorporate reconstruction of this segment into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of riverward levee slopes at a minimum 2.5H:1V slope angles. Reconstruct the levee toe, install large woody debris structures, excavate a mid-slope bench/buttress, and re-vegetate with live willow layers and native riparian trees and shrubs.							
89%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$1,107,766	Medium	District capital funding	Short-term
FL8018: Desimone Levee #2—Repairs to this levee segment should be incorporated into a reach-length levee setback with acquisition of sufficient easement area for reconstruction of the levee slopes at a minimum 2.5H:1V slope angle. The levee toe buttress should be reconstructed with installation of large woody debris structures, the excavation of a mid-slope bench/buttress re-vegetated with live willow layers and native riparian vegetation. The upper levee slopes should also be re-vegetated.							
89%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$1,380,547	Medium	District capital funding	Short-term
FL-8019: Desimone Levee #3—Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of levee slopes at a minimum 2.5H:1V slope angle. The levee toe should be reconstructed using large woody debris structures, and a mid-slope bench/buttress should be constructed. Upper levee slopes should then be stabilized.							
95%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$837,066	Low	District capital funding	Short-term
FL8020: Desimone Levee #4—Repair of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of the riverward levee slope at a minimum 2.5H:1V slope angle. This will require negotiations with local property owners concerning vacation of the railroad spur line serving these warehouses. This project should include reconstruction of the levee toe, installation of large woody debris structures, excavation of a mid-slope bench/buttress, re-vegetated with live willow layers and native riparian trees and shrubs, and stabilization of the upper bank.							
92%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$4,509,835	Medium	District capital funding	Short-term
FL8021: Reddington Levee Setback—Setback an existing levee from River Mile 29.5 (Brannan Park in Auburn) to River Mile 28.6, and extend protection by building a new levee from River Mile 28.6 to River Mile 27.62 (South 277th St.) to provide increased flood protection and improved habitat functions.							
68%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$3,103,254	Medium	District capital funding	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
Green River Basin (continued)							
FL8022: Segale Levees #2 and #3—Stabilization of this levee segment should be incorporated into a reach-length levee setback relocation with acquisition of sufficient easement area for reconstruction of the levee slopes at a minimum 2.5H:1V slope angle. A levee toe buttress should be constructed with large woody debris structures and excavation of a mid-slope bench/buttress stabilized and re-vegetated with live willow layers and native riparian vegetation. The upper levee slopes should also be stabilized.							
97%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$6,173,287	High	District capital funding	Short-term
FL8024: South Park Duwamish Backwater Inundation at 4th and Trenton Storm Drain—Reduce flooding from Duwamish backwater inundation in the 7th Ave S drainage basin in the South Park neighborhood.							
79%	Existing	FL, SW, DF	1, 2, 6, 8, 10, 11	$4,522,727	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term
FL8025: Gaco Western—Rehabilitate existing levee to reduce the risk of flooding in the Lower Green River.							
82%	Existing	FL, EQ, DF	1, 2, 6, 8, 10, 11	$548,575	Low	District capital funding	Short-term
FL8031: Gateway Lower/Codiga Repair—Repair slump in riverbank adjacent to Green river Trail which threatens train and adjacent commercial property.							
55%	Existing	FL	1, 6, 8, 10	$150,000	Low	District capital funding	Short-term
FL8034: Reddington Levee Extension—Build a new levee from River Mile 28.6 to River Mile 27.6 to extend existing Reddington Levee to high ground at 277th in Auburn.							
84%	New	FL, EQ, DF	6, 8, 10, 11	$4,789,703	Medium	District capital funding	Short-term
FL8039: Boeing Setback Levee—Stabilize riverbank by creating a mid-slope bench and reconstructing the lower embankment slopes and levee toe.							
95%	Existing	FL	1, 6, 10, 11	$2,853,846	Medium	District capital funding	Short-term
FL8040: Russell Rd Lowest—Set road back from river and reconstruct lower bank using current design and construction methods.							
68%	Existing	FL, EQ, DF	1, 6, 10, 11	$2,853,846	Medium	District capital funding	Short-term
FL8041: Horseshoe Bend Acquisition and Reconnection—Repair lower slope erosion and undercutting of toe, lower and upper slope slumping, deep-seated cracks developing in paved trail section.							
95%	Existing	FL, DF	1, 6, 10, 11	$30,000,000	Medium	District capital funding, FEMA hazard mitigation grants, FCAAP for property Acquisition	Short-term
FL8042: Lones Levee Extension—Construction of new levee from the existing Lones levee at River Mile 30.9 to high ground at the 8th Street bridge in Auburn.							
89%	New	FL, EQ, DF	6, 8, 10, 11	$3,974,608	Medium	District capital funding	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
White River Basin							
FL9001: County line to A-Street Flood Conveyance Improvement—Acquire the remaining private property via fee simple or flood easement purchase to implement this levee modification project. Reconnect the active channel to its left overbank floodplain by breaching the County-Line Levee, allowing for improved flood flow conveyance into the existing floodplain area and for the restoration of river channel processes through the reach. Remove an existing concrete culvert.							
58%	Existing	FL, VO, EQ, DF	1, 2, 5, 9, 10, 11	$2,636,796	Medium	District capital funding	Short-term
FL9002: Red Creek Acquisitions—In this high hazard area, at-risk residential homes should be acquired and removed. Land areas disturbed during removal of structures should be restored to a natural grade and replanting with native plants. Future development should be prohibited from flood and channel migration hazard zones.							
71%	Existing	FL, VO, DF	5, 6, 9, 10, 11	$1,322,804	Medium	District capital funding, FEMA hazard mitigation grants, FCAAP	Short-term
FL9004: White-Greenwater Acquisition—Acquire the property and remove the at-risk residential and rental structures. Remove the concrete flood wall and restore the riverbank to a natural floodplain condition.							
66%	Existing	FL, VO, DF	5, 6, 9, 10, 11	$1,363,628	Medium	District capital funding	Short-term
FL9007: Pacific Right Bank Acquisition and Setback Berm—Acquire land, conduct feasibility, modeling, design and permitting to build a new setback levee, removing existing revetment and restoring wetlands to reduce flood risks to residential community and some commercial areas.							
TBD	New and Existing	FL, DF, VO	3, 5, 6, 10	$7,136,662	High	District capital funding	Short-term
FL90XX – Trans Canada Levee Modification—Evaluate, design and implement levee modifications to improve flood conveyance.							
34%	New and existing	FL, VO, DF	1, 3, 6, 10	$7,136,662	High	District capital funding	Short-term

TABLE 17-4 (continued).
HAZARD MITIGATION ACTION PLAN MATRIX

Risk Factor	Applies to New or Existing Assets	Hazards Mitigated	Objectives Met	Estimated Cost	Cost Factor	Sources of Funding	Timeline
All Basins							
PRO-1-Continue to support the River Channel Maintenance program including channel monitoring for sediment management, vegetation management, naturally occurring woody debris management, and naturally occurring landslide management.							
84%	Both	All Hazards	1, 2, 11	$8,168,214	High	District capital funding	Short-term Ongoing
PRO-2: Continue to support hazard planning activities, the public awareness strategy and grant writing and administration.							
92%	Both	All Hazards	6, 10, 11	$2,837,046	Medium	District capital funding, FEMA hazard mitigation grant, FCAAP	Short-term Ongoing
PRO-3: Continue to support activities that provide technical analyses of watershed hydrology and rive channel hydraulics including but not limited to hydraulic modeling, flood studies and maps, channel migration studies and maps, and sediment management studies.							
95%	Both	All Hazards	3, 6	$8,025,240	High	District capital funding, FEMA Risk MAP, FCAAP	Short-term Ongoing
PRO-4: Continue to support activities that maintain the Flood Hazard Education and Flood Preparedness Program and the Flood Warning Program.							
100%	Both	All Hazards	4, 7	$2,016,636	Medium	District capital funding	Short-term Ongoing
PRO-5: Continue to support activities that maintain King County's compliance and good standing under the National Flood Insurance Program							
92%	Both	FL	3, 9	$1,440,000	Low	District capital Funding	Short-term Ongoing
PRO-6: Continue to support activities that maintain King County's class under the Community Rating System.							
92%	Both	All Hazards	3, 4, 7, 9	$1,410,000	Low	District capital Funding	Short-term Ongoing

**TABLE 17-5.
ACTION PLAN PRIORITIZATION**

Initiative Number	# of Objectives Met	Benefits	Costs	Benefits Equal or Exceed Costs	Grant-Eligible	Can Be Funded Under Existing Programs or Budgets	Priority
FL0001	5	High	Low	Yes	Yes	Yes	High
FL0004	5	High	Medium	Yes	Yes	Yes	High
FL0005	5	High	Low	Yes	Yes	Yes	High
FL0010	5	Medium	Low	Yes	Yes	Yes	High
FL1002	5	High	Low	Yes	No	Yes	High
FL1003	5	High	Low	Yes	Yes	Yes	High
FL1017	5	High	High	Yes	No	Yes	High
FL1019	3	High	Low	Yes	No	Yes	High
FL1022	5	High	Medium	Yes	No	Yes	High
FL1023	4	High	Low	Yes	Yes	Yes	High
FL2001	5	High	High	Yes	Yes	Yes	High
FL2002	5	High	Low	Yes	No	Yes	High
FL2010	5	Low	Low	Yes	No	Yes	High
FL2012	5	High	Medium	Yes	No	Yes	High
FL2013	5	High	Low	Yes	Yes	Yes	High
FL2014	5	High	Medium	Yes	Yes	Yes	High
FL2015	5	High	Medium	Yes	No	Yes	High
FL2019	5	High	Low	Yes	No	Yes	High
FL2020	4	High	Low	Yes	Yes	Yes	High
FL3004	5	High	Low	Yes	Yes	Yes	High
FL3005	5	High	Low	Yes	Yes	Yes	High
FL3007	5	Medium	Medium	Yes	No	Yes	High
FL3008	5	High	Medium	Yes	Yes	Yes	High
FL3009	5	High	Medium	Yes	No	Yes	High
FL4001	5	High	Low	Yes	Yes	Yes	High
FL4016	5	High	High	Yes	No	Yes	High
FL4021	5	Medium	High	No	Yes	Yes	Medium
FL4022	3	Medium	Low	Yes	Yes	Yes	High
FL5001	5	Medium	Low	Yes	Yes	Yes	High
FL6001	5	High	Medium	Yes	Yes	Yes	High
FL6002	5	High	Low	Yes	Yes	Yes	High
FL7004	5	High	Low	Yes	Yes	Yes	High
FL7005	4	High	Low	Yes	Yes	Yes	High
FL7006	5	High	Medium	Yes	No	Yes	High
FL7014	5	High	Medium	Yes	No	Yes	High

TABLE 17-5 (continued).
ACTION PLAN PRIORITIZATION

Initiative Number	# of Objectives Met	Benefits	Costs	Benefits Equal or Exceed Costs	Grant-Eligible	Can Be Funded Under Existing Programs or Budgets	Priority
FL7015	5	High	Medium	Yes	No	Yes	High
FL7016	7	High	Medium	Yes	No	Yes	High
FL7017	5	High	Medium	Yes	No	Yes	High
FL7018	3	High	Low	Yes	No	Yes	High
FL7020	4	High	Medium	Yes	No	Yes	High
FL7021	3	High	Low	Yes	Yes	Yes	High
FL7022	3	High	High	Yes	Yes	Yes	High
FL7023	7	Medium	Low	Yes	Yes	Yes	High
FL7024	7	High	Low	Yes	Yes	Yes	High
FL7037	5	High	Low	Yes	Yes	Yes	High
FL7039	7	High	Medium	Yes	Yes	Yes	High
FL7040	6	High	Low	Yes	Yes	Yes	High
FL8016	6	High	Low	Yes	No	Yes	High
FL8017	7	High	Medium	Yes	No	Yes	High
FL8018	5	High	High	Yes	No	Yes	High
FL8019	6	High	Medium	Yes	No	Yes	High
FL8020	6	High	Medium	Yes	No	Yes	High
FL8021	7	High	Medium	Yes	No	Yes	High
FL8022	7	High	High	Yes	No	Yes	High
FL8024	7	High	Medium	Yes	Yes	Yes	High
FL8025	7	High	High	Yes	No	Yes	High
FL8031	7	Medium	Medium	Yes	No	Yes	High
FL8034	7	High	Low	Yes	No	Yes	High
FL8039	4	High	Low	Yes	No	Yes	High
FL8040	4	High	Medium	Yes	No	Yes	High
FL8041	4	High	Medium	Yes	Yes	Yes	High
FL8042	4	High	Medium	Yes	No	Yes	High
FL9001	4	Medium	Medium	Yes	No	Yes	High
FL9002	4	High	Medium	Yes	Yes	Yes	High
FL9004	7	High	Medium	Yes	Yes	Yes	High
FL9007	5	High	Medium	Yes	No	Yes	High
FL90XX	4	Low	Medium	No	No	Yes	Medium
PRO-1	3	High	High	Yes	No	Yes	High
PRO-2	3	High	High	Yes	No	Yes	High

**TABLE 17-5 (continued).
ACTION PLAN PRIORITIZATION**

Initiative Number	# of Objectives Met	Benefits	Costs	Benefits Equal or Exceed Costs	Grant-Eligible	Can Be Funded Under Existing Programs or Budgets	Priority
PRO-3	2	High	High	Yes	Yes	Yes	High
PRO-4	2	High	Medium	Yes	Yes	Yes	High
PRO-5	2	High	High	Yes	No	Yes	High
PRO-6	4	High	Low	Yes	No	Yes	High

17.6 ANALYSIS OF MITIGATION ACTIONS

Local hazard mitigation plans must identify and analyze a comprehensive range of mitigation actions (44CFR, Section 201.6(c)(3)(iii)). To illustrate the range of actions identified in this plan, the action plan was reviewed and each initiative was classified as one of the following mitigation types:

- **Prevention:** Government, administrative or regulatory actions or processes that influence the way land and buildings are developed and built. These actions also include public activities to reduce hazard losses. Examples include planning and zoning, floodplain local laws, capital improvement programs, open space preservation, and storm water management regulations.
- **Property Protection:** Actions that involve:
  - Modification of existing buildings or structures to protect them from a hazard, or
  - Removal of the structures from the hazard area.

  Examples include acquisition, elevation, relocation, structural retrofits, storm shutters, and shatter-resistant glass.
- **Public Education and Awareness:** Actions to inform and educate citizens, elected officials, and property owners about hazards and potential ways to mitigate them. Such actions include outreach projects, real estate disclosure, hazard information centers, and school-age and adult education programs.
- **Natural Resource Protection:** Actions that minimize hazard loss and also preserve or restore the functions of natural systems. These actions include sediment and erosion control, stream corridor restoration, watershed management, forest and vegetation management, and wetland restoration and preservation.
- **Emergency Services:** Actions that protect people and property during and immediately following a disaster or hazard event. Services include warning systems, emergency response services, protection of essential facilities and post-disaster actions such as debris management and grant writing.
- **Structural Projects:** Actions that involve the construction of structures to reduce the impact of a hazard event by manipulation of the hazard. Such structures include dams, setback levees, floodwalls, retaining walls, and safe rooms.

Table 17-6 shows the breakdown of the actions into these categories. Some initiatives can meet multiple categories.

TABLE 17-6.
ANALYSIS OF MITIGATION ACTIONS

	Prevention[a]	Property Protection	Public Education and Awareness	Natural Resource Protection	Emergency Services	Structural Projects
Dam Failure	FL2015, FL2010, FL2019, FL7014, FL7017, FL8025, FL8041, FL9007, FL90XX, PRO-1, PRO-2, PRO-3	FL2014, FL2020, FL3004, FL3005, FL3008, FL3009, FL7004, FL7005, FL7021, FL7022, FL7023, FL7037, FL7039, FL7040, FL9002, FL9004	FL2010, FL7014, FL7017, PRO-2, PRO-3	FL2013, FL3004, FL3005, FL3007, FL3009, FL7005, FL7015, FL7016, FL7018, FL7037, FL7020, FL7039, FL7040, FL8017, FL8018, FL8019, FL8020, FL8021, FL8022, FL8034, FL9001	PRO-2, PRO-4	FL2013, FL3004, FL3007, FL3009, FL7015, FL 7016, FL7021, FL7022, FL7024, FL7037, FL7020, FL7039, FL8017, FL8018, FL8019, FL8020, FL8021, FL8022, FL8024, FL8034, FL8040, FL8042, FL9001
Earthquake	FL1022, FL2001, FL8025, PRO-1, PRO-2, PRO-3	FL0005, FL1002, FL1023, FL2001, FL2014, FL2020, FL3004, FL3008, FL3009, FL7004, FL7021, FL7022, FL7023, FL7037, FL7039, FL7040	FL2010, PRO-2, PRO-3	FL2012, FL2013, FL3004, FL3007, FL7015, FL7016, FL7037, FL7020, FL7039, FL7040, FL8017, FL8018, FL8019, FL8020, FL8021, FL8022, FL8034	PRO-2, PRO-4	FL1003, FL1019, FL1022, FL2012, FL2013, FL3004, FL3007, FL 3009, FL7015, FL7016, FL7021, FL7022, Fl7037, FL7020, FL7039, FL8017, FL8018, FL8019, FL8020, FL8021, FL8022, FL8034, FL8040, FL8042
Flood	FL1017, FL1022, FL2001, FL2015, FL2010, FL2019, FL4016, FL4021, FL4022, FL7014, FL7017, FL8025, FL8031, FL8039, FL8041, FL9007, FL90XX, PRO-1, PRO-2, PRO-3, PRO-5, PRO-6	FL0001, FL0004, Fl0005, FL1002, FL1023, FL2001, FL2014, FL2020, FL3004, FL 3005, FL 3008, FL3009, FL4001, FL6002, FL7004, FL7005, FL7021, FL7022, FL7023, FL7037, FL7039, FL7040, FL9002, FL9004	FL2010, FL7014, FL7017, PRO-2, PRO-3	FL2012, FL2013, FL3004, FL3005, FL3007, FL 3009, FL4016, FL5001, FL7005, FL7015, FL7016, FL7006, FL7018, FL7037, FL7020, FL7039, FL7040, FL8016, FL8017, FL8018, FL8019, FL8020, FL8021, FL8022, FL8034, FL9001	PRO-2, PRO-4	FL0010, FL1003, FL1019, FL1022, Fl2002, FL2012, FL2013, FL3004, FL3007, FL3009, FL5001, FL6001, FL7015, FL7016, FL7006, FL7021, FL7022, FL7024, FL7037, FL7020, FL7039, FL8016, FL8017, FL8018, FL8019, FL8020, FL8021, FL8022, FL8024, FL8034, FL8040, FL8042, FL9001
Landslide	PRO-1, PRO-2, PRO-3	FL2014, FL7005, FL7022, FL7039, FL7040	FL2010, PRO-2, PRO-3	FL2013, FL7005, FL7039, FL7040	PRO-2, PRO-4	FL2013, FL7022, FL7039
Severe Weather	PRO-1, PRO-2, PRO-3		FL2010, PRO-2, PRO-3		PRO-2, PRO-4	FL8024
Volcano	FL9007, FL90XX, PRO-1, PRO-2, PRO-3	FL9002, FL9004	FL2010, PRO-2, PRO-3	FL9001	PRO-2, PRO-4	FL9001
Wildland Fire	PRO-1, PRO-2, PRO-3		FL2010, PRO-2, PRO-3		PRO-2, PRO-4	

a. Preventive actions that include regulations with permitting authority fall outside the capabilities of the district

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APPENDIX A. ACRONYMS AND DEFINITIONS

March 2010

APPENDIX A.
ACRONYMS AND DEFINITIONS

ACRONYMS

Acronym	Definition	Acronym	Definition
CFR	Code of Federal Regulations	HAZUS-MH	Hazards, United States-Multi Hazard
CRS	Community Rating System	NEHRP	National Earthquake Hazards Reduction Program
DMA	Disaster Mitigation Act	NFIP	National Flood Insurance Program
ESA	Endangered Species Act	PGA	Peak Ground Acceleration
FCAAP	Flood Control Account Assistance Program	PUD	Public Utility District
FEMA	Federal Emergency Management Agency	RCW	Revised Code of Washington
FIRM	Flood Insurance Rate Map	USGS	United States Geological Survey
GIS	Geographic Information System	WRIA	Water Resource Inventory Area
GMA	Growth Management Act		

DEFINITIONS

100-Year Flood: The term "100-year flood" can be misleading. The 100-year flood does not necessarily occur once every 100 years. Rather, it is the flood that has a 1 percent chance of being equaled or exceeded in any given year. Thus, the 100-year flood could occur more than once in a relatively short period of time. The Federal Emergency Management Agency (FEMA) defines it as the 1 percent annual chance flood, which is now the standard definition used by most federal and state agencies and by the National Flood Insurance Program (NFIP).

Ash fall: Volcanoes tend to erupt lavas so thick and charged with gases that they explode into ash rather than flow.

Asset: An asset is any man-made or natural feature that has value, including, but not limited to, people; buildings; infrastructure, such as bridges, roads, sewers, and water systems; lifelines, such as electricity and communication resources; and environmental, cultural, or recreational features such as parks, wetlands, and landmarks.

Base Flood: The flood having a 1% chance of being equaled or exceeded in any given year, also known as the "100-year" or "1% chance" flood. The base flood is a statistical concept used to ensure that all properties subject to the National Flood Insurance Program (NFIP) are protected to the same degree against flooding.

Benefit: A benefit is a net project outcome and is usually defined in monetary terms. Benefits may include direct and indirect effects. For the purposes of benefit-cost analysis of proposed mitigation measures, benefits are limited to specific, measurable, risk reduction factors, including reduction in expected property losses (buildings, contents, and functions) and protection of human life.

Benefit/Cost Analysis: A benefit/cost analysis is a systematic, quantitative method of comparing projected benefits to projected costs of a project or policy. It is used as a measure of cost effectiveness.

Benioff Earthquake: Sometimes called "deep quakes," these occur in the Pacific Northwest when the Juan de Fuca plate breaks up underneath the continental plate, approximately 30 miles beneath the earth's surface.

Building: A building is defined as a structure that is walled and roofed, principally aboveground, and permanently fixed to a site. The term includes manufactured homes on permanent foundations on which the wheels and axles carry no weight.

Capability Assessment: A capability assessment provides a description and analysis of a community's current capacity to address threats associated with hazards. The assessment includes two components: an inventory of an agency's mission, programs, and policies, and an analysis of its capacity to carry them out. A capability assessment is an integral part of the planning process in which a community's actions to reduce losses are identified, reviewed, and analyzed, and the framework for implementation is identified. The following capabilities were reviewed under this assessment:

- Legal and regulatory capability
- Administrative and technical capability
- Fiscal capability

Community Rating System (CRS): The CRS is a voluntary program under the NFIP that rewards participating communities (provides incentives) for exceeding the minimum requirements of the NFIP and completing activities that reduce flood hazard risk by providing flood insurance premium discounts.

Critical Area: An area defined by state or local regulations as deserving special protection because of unique natural features or its value as habitat for a wide range of species of flora and fauna. A sensitive/critical area is usually subject to more restrictive development regulations.

Critical Facility: A critical facility is vital to the ability to provide essential services and protect life and property. Loss of a critical facility would result in a severe economic or catastrophic impact. Critical facilities can be segregated into three categories:

- Facilities that are essential to the ability to respond and recover from the impacts of natural hazards
- Facilities that need early warning to enable them to prepare for and respond to the impacts of natural hazards,
- Facilities that by the nature of their operations create an exposure to secondary hazards of concern.

Under the hazard mitigation plan definition, critical facilities include but are not limited to the following:

- Police stations, fire stations, government facilities (including those that house critical Information Technology and Communication infrastructure), vehicle and equipment storage facilities, and emergency operations centers needed for disaster response before, during, and after hazard events
- Public and private utilities and infrastructure including data and server communication facilities, vital to maintaining or restoring normal services to areas damaged by hazard events
- Educational facilities, including K-12

- Hospitals, nursing homes, and housing likely to contain occupants who may not be sufficiently mobile to avoid death or injury during a hazard event
- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic, and/or water-reactive materials.

Crustal Earthquake: Crustal quakes occur at a depth of 5 to 10 miles beneath the earth's surface and are associated with fault movement within a surface plate.

Cubic Feet per Second (cfs): Discharge or river flow is commonly measured in cfs. One cubic foot is about 7.5 gallons of liquid.

Dam: Any artificial barrier or controlling mechanism that can or does impound 10 acre-feet or more of water.

Debris Avalanche: Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 100 mph.

Debris Flow: Dense mixtures of water-saturated debris that move down-valley; looking and behaving much like flowing concrete. They form when loose masses of unconsolidated material are saturated, become unstable, and move down slope. The source of water varies but includes rainfall, melting snow or ice, and glacial outburst floods.

Debris Slide: Debris slides consist of unconsolidated rock or soil that has moved rapidly down slope. They occur on slopes greater than 65 percent.

Disaster Mitigation Act of 2000 (DMA); The DMA is Public Law 106-390 and is the latest federal legislation enacted to encourage and promote proactive, pre-disaster planning as a condition of receiving financial assistance under the Robert T. Stafford Act. The DMA emphasizes planning for disasters before they occur. Under the DMA, a pre-disaster hazard mitigation program and new requirements for the national post-disaster hazard mitigation grant program were established.

Drainage Basin: A basin is the area within which all surface water- whether from rainfall, snowmelt, springs or other sources- flows to a single water body or watercourse. The boundary of a river basin is defined by natural topography, such as hills, mountains and ridges. Drainage basins are also referred to as **watersheds** or **basins**.

Flood Insurance Rate Map (FIRM): FIRMs are the official maps on which the Federal Emergency Management Agency (FEMA) has delineated the Special Flood Hazard Area.

Flood Insurance Study: A report published by the Federal Insurance and Mitigation Administration for a community in conjunction with the community's Flood Insurance rate Map. The study contains such background data as the base flood discharges and water surface elevations that were used to prepare the FIRM. In most cases, a community FIRM with detailed mapping will have a corresponding flood insurance study.

Floodplain: Any land area susceptible to being inundated by flood waters from any source. A flood insurance rate map identifies most, but not necessarily all, of a community's floodplain as the Special Flood Hazard Area.

Floodway: Floodways are areas within a floodplain that are reserved for the purpose of conveying flood discharge without increasing the base flood elevation more than 1 foot. Generally speaking, no development is allowed in floodways, as any structures located there would block the flow of floodwaters.

General Building Stock: The general building stock within a planning area are those buildings, residences and facilities that are not in public ownership or identified as critical or essential facilities.

Hazard Mitigation Grant Program: Authorized under Section 202 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the program is administered by FEMA and provides grants to states, tribes, and local governments to implement hazard mitigation actions after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to disasters and to enable mitigation activities to be implemented as a community recovers from a disaster

Hazards U.S. Multi-Hazard (HAZUS-MH) Loss Estimation Program: HAZUS-MH is a GIS-based program used to support the development of risk assessments as required under the DMA. The HAZUS-MH software program assesses risk in a quantitative manner to estimate damages and losses associated with natural hazards. HAZUS-MH is FEMA's nationally applicable, standardized methodology and software program and contains modules for estimating potential losses from earthquakes, floods, and wind hazards. HAZUS-MH has also been used to assess vulnerability (exposure) for other hazards.

Lahar: A debris flow composed of a significant component of volcanic material.

Landslide: Landslides can be described as the sliding movement of masses of loosened rock and soil down a hillside or slope. Fundamentally, slope failures occur when the strength of the soils forming the slope exceeds the pressure, such as weight or saturation, acting upon them.

Liquefaction: Liquefaction is the complete failure of soils, occurring when soils lose shear strength and flow horizontally. It is most likely to occur in fine grain sands and silts, which behave like viscous fluids when liquefaction occurs. This situation is extremely hazardous to development on the soils that liquefy, and generally results in extreme property damage and threats to life and safety.

Local Government: Any county, municipality, city, town, township, public authority, school district, special district, intrastate district, council of governments (regardless of whether the council of governments is incorporated as a nonprofit corporation under State law), regional or interstate government entity, or agency or instrumentality of a local government; any Indian tribe or authorized tribal organization, or Alaska Native village or organization; and any rural community, unincorporated town or village, or other public entity.

Magnitude: Magnitude is the measure of the strength of an earthquake, and is typically measured by the Richter scale. As an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Mass movement: A collective term for landslides, mudflows, debris flows, sinkholes and lahars.

Mitigation: A preventive action that can be taken in advance of an event that will reduce or eliminate the risk to life or property.

Mitigation Actions: Mitigation actions are specific actions to achieve goals and objectives that minimize the effects from a disaster and reduce the loss of life and property.

Objective: For the purposes of this plan, an objective is defined as a short-term aim that, when combined with other objectives, forms a strategy or course of action to meet a goal. Unlike goals, objectives are specific and measurable.

Peak Ground Acceleration: Peak Ground Acceleration (PGA) is a measure of the highest amplitude of ground shaking that accompanies an earthquake, based on a percentage of the force of gravity.

Planning Committee: The planning committee is the group that oversaw all phases of the hazard mitigation plan’s development. The members of this committee included key district personnel, citizens, and other stakeholders from within the planning area.

Preparedness: Preparedness refers to actions that strengthen the capability of government, citizens, and communities to respond to disasters.

Presidential Disaster Declaration: These declarations are typically made for events that cause more damage than state and local governments and resources can handle without federal government assistance. Generally, no specific dollar loss threshold has been established for such declarations. A Presidential Disaster Declaration puts into motion long-term federal recovery programs, some of which are matched by state programs, designed to help disaster victims, businesses, and public entities.

Probability of Occurrence: The probability of occurrence is a statistical measure or estimate of the likelihood that a hazard will occur. This probability is generally based on past hazard events in the area and a forecast of events that could occur in the future. A probability factor based on yearly values of occurrence is used to estimate probability of occurrence.

Pyroclastic Flow: Pyroclastic flows are avalanches of hot ash, rock fragments and gas that move at high speeds down the sides of a volcano during explosive eruptions or when the edge of a thick, viscous, lava flow or dome breaks apart or collapses. Speeds range from 20 to more than 200 miles per hour.

Repetitive Loss Property: Any NFIP-insured property that, since 1978 and regardless of any changes of ownership during that period, has experienced:

- Four or more paid flood losses in excess of $1000.00; or
- Two paid flood losses in excess of $1000.00 within any 10-year period since 1978 or
- Three or more paid losses that equal or exceed the current value of the insured property.

Return Period (or Mean Return Period): This term refers to the average period of time in years between occurrences of a particular hazard (equal to the inverse of the annual frequency of occurrence).

Riparian- Relating to or inhabiting the banks of a natural course of water. Riparian zones are ecologically diverse and contribute to the health of other aquatic ecosystems by filtering out pollutants and preventing erosion. Salmon in the Pacific Northwest feed off riparian insects; trees such as the black walnut, the American sycamore, and the cottonwood thrive in riparian environments.

Riverine: Of or produced by a river. Riverine floodplains have readily identifiable channels. Floodway maps can only be prepared for riverine floodplains.

Risk: Risk is the estimated impact that a hazard would have on people, services, facilities, and structures in a community. Risk measures the likelihood of a hazard occurring and resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to occurrence of a specific type of hazard. Risk also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Sinkhole: A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

Slab: This refers to one or more layers of snow in which the grains are bonded together. A slab initially fails over a large area instead of at a single point.

Special Flood Hazard Area: The base floodplain delineated on a Flood Insurance Rate Map. The special flood hazard area is mapped as a Zone A in riverine situations and zone V in coastal situations. The special flood hazard area may or may not encompass all of a community's flood problems

Stafford Act: The Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 100-107, was signed into law on November 23, 1988. This law amended the Disaster Relief Act of 1974, Public Law 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

Stakeholder: Business leaders, civic groups, academia, non-profit organizations, major employers, managers of critical facilities, farmers, developers, special purpose districts, and others whose actions could impact hazard mitigation.

Stream Bank Erosion: Stream bank erosion is common along rivers, streams and drains where banks have been eroded, sloughed or undercut. However, it is important to remember that a stream is a dynamic and constantly changing system. It is natural for a stream to want to meander, so not all eroding banks are "bad" and in need of repair. Generally, stream bank erosion becomes a problem where development has limited the meandering nature of streams, where streams have been channelized, or where stream bank structures such as bridges and culverts are located in places where they can actually cause damage to downstream areas. Stabilizing these areas can help protect watercourses from continued sedimentation, damage to adjacent land uses, control unwanted meander, and improvement of habitat for fish and wildlife.

Steep Slope: Different communities and agencies define it differently, depending on what it is being applied to, but generally a steep slope is a slope in which the percent slope equals or exceeds 25%. For this study, steep slope is defined as slopes greater than 33%.

Subduction Zone Earthquake: This type of quake occurs along two converging plates, attached to one another along their interface. When the interface between these two plates slips, a sudden, dramatic release of energy results, propagated along the entire fault line.

Sustainable Hazard Mitigation: This concept includes the sound management of natural resources, local economic and social resiliency, and the recognition that hazards and mitigation must be understood in the largest possible social and economic context.

Tephra: The ash and the large volcanic projectiles that erupt from a volcano into the atmosphere are called tephra. The largest fragments (2½ inches) fall back to the ground fairly near the vents, as close as a few feet and as far as 6 mi. The smallest rock fragments (ash) are composed of rock, minerals, and glass that are less than 1/8 inch in diameter. Tephra plume characteristics are affected by wind speed, particle size, and precipitation.

Thunderstorm: A thunderstorm is a storm with lightning and thunder produced by cumulonimbus clouds. Thunderstorms usually produce gusty winds, heavy rains, and sometimes hail. Thunderstorms are usually short in duration (seldom more than 2 hours). Heavy rains associated with thunderstorms can lead to flash flooding during the wet or dry seasons.

Vulnerability: Vulnerability describes how exposed or susceptible an asset is to damage. Vulnerability depends on an asset's construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power. Flooding of an electric substation would affect not only the substation itself but businesses as well. Often, indirect effects can be much more widespread and damaging than direct effects.

Water Resource Inventory Area (WRIA): WRIAs were formalized under Washington Administrative Code 173-500-040 and authorized under the Water Resources Act of 1971, RCW 90.54. Ecology was given the responsibility for the development and management of these administrative and planning boundaries. These boundaries represent the administrative under pinning of this agency's business activities. The original WRIA boundary agreements and judgments were reached jointly by Washington's natural resource agencies (Ecology, Natural Resources, Fish and Wildlife) in 1970.

Watershed: A watershed is an area that drains downgradient from areas of higher land to areas of lower land to the lowest point, a common drainage basin.

Wildfire or Wildland Fire: These terms refer to any uncontrolled fire occurring on undeveloped land that requires fire suppression. The potential for wildfire is influenced by three factors: the presence of fuel, topography, and air mass. Fuel can include living and dead vegetation on the ground, along the surface as brush and small trees, and in the air such as tree canopies. Topography includes both slope and elevation. Air mass includes temperature, relative humidity, wind speed and direction, cloud cover, precipitation amount, duration, and the stability of the atmosphere at the time of the fire. Wildfires can be ignited by lightning and, most frequently, by human activity including smoking, campfires, equipment use, and arson.

Wild and Scenic River: A federal designation that is intended to protect the natural character of rivers and their habitat without adversely affecting surrounding property.

Windstorm: Windstorms are generally short-duration events involving straight-line winds or gusts exceeding 50 mph. These gusts can produce winds of sufficient strength to cause property damage. Windstorms are especially dangerous in areas with significant tree stands, exposed property, poorly constructed buildings, mobile homes (manufactured housing units), major infrastructure, and aboveground utility lines. A windstorm can topple trees and power lines; cause damage to residential, commercial, critical facilities; and leave tons of debris in its wake.

Zero-Rise Floodway: A 'zero-rise' floodway is an area reserved to carry the discharge of a flood without raising the base flood elevation. Some communities have chosen to implement zero-rise floodways because they provide greater flood protection than the floodway described above, which allows a one foot rise in the base flood elevation.

Zoning Ordinance: The zoning ordinance designates allowable land use and intensities for a local jurisdiction. Zoning ordinances consist of two components: a zoning text and a zoning map.